Sea turtles and small-scale fisheries:
Designing conservation policies for a
marine area on Crete, Greece

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Aliki Panagopoulou

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Dedication

To Laurie Spotila:

An amazing woman I was honored to have in my life and call a friend.

I miss you!

And

To my nephews, Konstandinos and Michalis:

You are my secret power!

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CCL	Curved Carapace Length
CCW	Curved Carapace Width
CITES	Convention on the International Trade of Endangered Species
CMS	Convention for Migratory Species (Bonn Convention)
ECF	Estimated Clutch Frequency
EU	European Union (former EEC)
EEC	European Economic Community (now European Union)
FEK	Fishermen’s Ecological knowledge
F/V	Fishing Vessel
GIS	Geographical Information System
GPS	Global Positioning System
HCMR	Hellenic Center for Marine Research
IMBC	Institute of Marine Biology of Crete (Now HCMR)
IUCN	International Union for the Conservation of Nature
MCP	Minimum Convex Polygon
NGO	Non-Governmental Organization
OCF	Observed Clutch Frequency
OIP	Observed Inter-nesting Period
PAT	Pop-up Archival Tag
SCI	Site of Community Importance (92/43/EEC Directive)
SCL	Straight Carapace Length
SCW	Straight Carapace Width
TAD	Time At Depth
UD	Utilization Distribution
UNEP/MAP	United Nations Environment Program/Mediterranean Action Plan (for the Barcelona Convention)

Abstract

Sea turtles and small-scale fisheries: Designing conservation policies

for a marine area on Crete, Greece

Aliki Panagopoulou

Supervisors: James R.Spotila, Ph.D. and Stephen J. Morreale, Ph.D.

The purpose of this interdisciplinary study was to provide scientific information that would contribute to the development and implementation of management policies for Rethymno, Crete. It hosted a loggerhead turtle rookery of regional importance for the Mediterranean region and was included in the EU's NATURA 2000 network of protected areas. I used satellite telemetry, data loggers and ultrasonography to study the behavior of sea turtles during the interesting interval. By deploying satellite transmitters on 21 turtles I identified internesting habitat utilized by loggerheads, which extended along the northern coast of Crete. Twenty five percent of turtles exhibited low site fidelity, likely depositing at least one clutch in areas up to 150 km away. Minimum Convex Polygon and Kernel Density analyses revealed areas of high intensity use by sea turtles indicating that existing boundaries of the NATURA 2000 site were insufficient to protect this population. Some females (n = 4) overwintered in neritic habitats around Crete. I studied the diving behavior of 33 loggerhead turtles during the interesting interval using dive depth, dive duration, time at depth and number of dives as proxies. Maximum dive depth occurred at depths shallower than 10 m (data loggers: 89.2%, n = 8,241; transmitters: 90.1%, n = 30,804), indicating selection for habitats providing protection. Using x^2 goodness of fit tests, I found variation in diving behavior among individual turtles. More

active behavioral patterns indicated selection for warmer waters or foraging. ANOVA analyses of time at depth, dive duration and number of dives per 4 h period showed variation in behavior during the day, with females spending > 95% of their time in the top 5 m of the water column between 11:00 and 19:00. Diving behaviors were consistent with energy conservation strategies. I conducted 101 semi-structured interviews with small-scale fishermen at 18 ports around Crete using a questionnaire. There was a link between observed decreases in catch (reported by 96.0% of respondents), increased fishing effort and an increase in intensity of interactions with sea turtles. Fishers discussed damages resulting from these interactions, but sea turtles were thought to pose limited (52.5%) or no threat (21.2%) to the local fishery. Interactions with large marine vertebrates were included in the ‘top three challenges’ faced by 66% of respondents, who indicated that the government should provide compensations, suggesting that it was indispensable to prevent intentional killings of animals seen as threats. Respondents also discussed establishing MPAs or areas closed to fishing as favorable interventions for regenerating fish stocks. They also suggested that closures would be acceptable, especially if temporary and combined with compensation for curtailed fishing access.

Chapter 1: General Introduction

Sea turtles are marine reptiles, occupying both oceanic and neritic environments, yet they are dependent on terrestrial habitats for their reproduction (Pritchard, 1997). Seven species of sea turtles are currently recognized: leatherbacks (*Dermochelys coriacea*), greens (*Chelonia mydas*), hawksbills (*Eretmochelys coriacea*), Kemp's and olive ridleys (*Lepidochelys kempii* and *Lepidochelys olivacea*), flatbacks (*Natator depressus*) and loggerheads (*Caretta caretta*) (Pritchard, 1997; Eckert et al., 1999). They are long-lived species characterized by delayed maturity and iteroparity (i.e. they lay multiple nests over multiple seasons within their lifetimes). They also exhibit extensive migrations that range from hundreds to thousands of kilometers (Plotkin, 2003; Bowen and Karl 2007; Southwood and Avens 2010). Sea turtles play a vital role in marine ecosystems, acting as consumers, hosts for parasites, substrates for communities of epibionts such as barnacles (*Chelonibia testudinaria*), transporters of nutrients, modifiers of seascape and prey to other organisms (Bouchard and Bjorndal 2000; Bjorndal and Jackson, 2003; Pfaller et al., 2006; Heithaus et al., 2007).

With the exception of flatbacks, listed as Data Deficient (DD), all sea turtle species have suffered declines over the last decades and are included in IUCN's List of Threatened Species ranging from Vulnerable (VU) to Critically Endangered (CR) (IUCN, 2015). Principal threats for sea turtles include the degradation of nesting habitats due to human related activities (Lutcavage et al., 1997), interactions with fisheries (e.g. Spotila et al., 2000; Lewison et al., 2004; Wallace et al., 2008; Casale and Margaritoulis, 2010; Lewison et al., 2014), egg harvesting and turtle meat consumption (e.g. Seminoff 2004; Santidian-Tomillo et al., 2008; Mancini and Koch, 2009), boat strikes (Lutcavage et al., 1997; Hazel and Gyuris 2006) and pollution (Bjorndal et al., 2011). The effects of climate change are further projected to impact sea turtle populations in the future (e.g. Fuentes et al., 2009; Robinson et al., 2009; Hawkes et al., 2009; Witt et al., 2010; Pikesley et al., 2014; Neeman et al., 2015).

Due to the widespread range and long-distance migrations exhibited by sea turtles, and limitations in both logistics and technology, for a long time critical stages in the life of sea turtles remained a mystery (Carr, 1988) and our knowledge for the most part was derived from direct and indirect observations such as tag returns, aerial surveys and observations not far from the coast (e.g. Carr and Ogren, 1960; Booth and Peters, 1972; Maylan et al., 1982; Mortimer and Carr, 1987; Epperly et al., 1995).

In recent years, thanks to the advances of modern technology and the development of new bio-logging techniques, many of these gaps in sea turtle ecology, behavior and physiology are closing. For example, satellite telemetry studies have provided insights on the sea turtle distribution, identified critical habitats and migratory routes, and highlighted behavioral patterns during foraging and/or overwintering (reviewed in Godley et al., 2008; Bailey et al., 2008; Hart et al., 2015), during the “lost years” (Casale and Mariani, 2014; Mansfield et al., 2014) and during internesting (e.g. Hart et al., 2010; Shillinger et al., 2010; Blanco et al., 2012).

All species of sea turtle share similar life history traits (Ehrhart, 1982; Van Buskirk and Crowder, 1994; Musick and Limpus, 1997; Bowen 2007). Their clutches are deposited on sandy beaches worldwide and after hatching the first few years in a turtle’s life are spent as pelagic juveniles (Carr and Ogren, 1960; Bolten, 2003). Once they reach a certain size these pelagic juveniles undergo an ontogenetic shift and move into neritic (over continental shelf) foraging grounds except for leatherbacks which have both neritic and oceanic foraging behaviour as juveniles and as adults (Robinson et al., 2014). After several years spent in foraging areas, reproductively mature and active males and females migrate towards the mating areas where they arrive several weeks before nesting begins (Limpus et al., 1992; Miller, 1997; Musick and Limpus, 1997; Schroeder, 2003; Plotkin 2003). Courtship and mating occurs in the oceanic waters away from the nesting grounds (Pritchard, 1982; Eckert and Eckert, 1989), opportunistically en route to the mating areas as males intercept females and copulate with them, or in close proximity to the nesting beaches (Plotkin, 2003; James et al. 2005; Rostal, 2007; Morreale et al., 2007).

After the mating season has finished, male turtles depart, presumably because with the females no longer being receptive to mating there is no benefit in males remaining in unfamiliar or resource-poor areas (Booth and Peters 1972; Ehrhart 1982; Plotkin et al., 1996; Hays et al. 2001; Hays et al., 2010). Females remain in the vicinity and come ashore to lay several clutches within the same reproductive season, with an internesting interval of about 14 days. After the last nest has been laid, females migrate back to their foraging habitats and it will take one to several years before they are ready to breed again (Miller 1997). Both males and females exhibit strong fidelity not only to their natal beaches, but also to their feeding areas (Limpus et al., 1992; Limpus and Limpus 2001; Bowen and Karl 2007; Broderick et al., 2007; Casale et al., 2007).

Loggerhead turtles (*Caretta caretta*) have the greatest geographic range of all sea turtle species and are able to thrive in both temperate and tropical latitudes (Dodd, 1988; Bolten, 2003). They are known to nest as high north as 35° latitude in the North Atlantic and 40° in the Mediterranean (Bowen, 2003; Bowen and Karl 2007; Sénégas et al., 2008), can be encountered in almost all oceanic basins and they inhabit both oceanic and neritic habitats (Bolten, 2003). Important nesting rookeries for loggerhead turtles can be found in Florida and the South-East US as well as in Oman, South Africa, Australia, and Japan. In addition, they are the most abundant of the three turtle species known to frequent the Mediterranean (Dodd, 1988; Bolten and Witherington, 2003; Margaritoulis et.al, 2003; Casale and Margaritoulis, 2010). Like other sea turtle species, they have been suffering declines over the last decades and are included in IUCN's List of Threatened Species as Endangered (IUCN, 2015). They are also listed as endangered in several international conventions (e.g. CITES, Barcelona Convention (UNEP/MAP), Convention on Migratory Species (CMS), Bern Convention). At a European level, they are classified as priority species in Appendices II and IV of the EU's Habitats Directive (92/43/EEC).

Mediterranean loggerheads originated from West Atlantic populations and they have genetically diverged forming a distinct, relatively isolated population (Bowen, 1993; Encalada et al, 1998; Bowen and Karl 2007; Shamblin et al., 2014). Colonization is estimated to have taken place at the end of the last Ice Age ca 10,000 – 12,000 years ago (Bowen et al., 1993; Encalada et al., 1998; Bowen and Karl 2007). However more recent research suggests that sea turtle colonization of the Mediterranean occurred during the Pleistocene, at ca. 65,000 years ago (Clusa et al., 2013). Current nesting in the region is concentrated mostly in the Eastern Basin with Greece, Turkey, Cyprus and Libya hosting the most important rookeries in terms of nest numbers (Margaritoulis et al., 2003; Casale and Margaritoulis 2010). With an average of 3,472 nests per season (range: 2,132 – 5,319), Greece hosts 60.6% of the recorded nesting activity for loggerhead sea turtles in the Mediterranean (Margaritoulis et al., 2003; Margaritoulis 2005; Casale and

Margaritoulis, 2010). Laganas Bay (Zakynthos), along with Kyparissia Bay (western Peloponnesus) and Rethymno (Crete) are among the largest nesting aggregations for the Mediterranean accounting for 45.7% of the total monitored nesting effort in the region (Margaritoulis, 2005). Important foraging areas have been identified along the coast of Libya, the Gulf of Gabès in Tunisia, the Adriatic Sea and in the Western Mediterranean basin where abundant immature loggerheads originating from the region, but also the Atlantic populations, can be encountered (Laurent et al., 1998; Margaritoulis et al., 2003; Carreras et al., 2006; Casale and Margaritoulis 2010; Clusa et al., 2014; Luschi and Casale 2014).

Like most sea turtle populations, loggerheads in the Mediterranean are in decline mostly due to anthropogenic impacts on their nesting habitats that impede the nesting process and cause increased mortality of hatchlings due to disorientation (Arianoutsou, 1988; Margaritoulis and Panagopoulou, 2010; Turkosan and Kaska, 2010; Casale and Margaritoulis, 2010). However, it has recently become apparent that the greatest threat for turtle populations in the Mediterranean is the adverse impact resulting from incidental captures in fishing gear.

During the 20th century, the increasing demand for fish led to more sophisticated fishing methods that exponentially increased the amounts of fish caught every year. The Mediterranean is one of the most heavily fished areas in the world (Lewison et al., 2004; Lleonard, 2005; Wallace et al., 2010; Lewison et al., 2014), where a variety of gear that range from small scale (set nets, trammel nets and demersal longlines) to bottom trawlers and pelagic longlines are used (Casale 2008). There is a distinction between in-shore, self-regulating fisheries that provide fish to support local communities and more intense, industrialized and profit-oriented fishing activity (Berkes 1985). Indeed, there appear to be two contrasting types of fishery: large-scale, high-catch industrial fisheries and small-scale fisheries. The former dominate the international and national markets and often use destructive gear that negatively impacts benthic habitats that the target species depend upon (Chuenpagdee et al., 2003; Preikshot and Pauly 2008; Chuenpagdee, 2012), discard 16-40 million tons of fish per year (Preikshot and Pauly, 2008) and process a further 20-30 million tons of fish into fishmeal for aquacultures (Jacquet and Pauly, 2008). Small-scale fisheries, use much smaller vessels with generally non-destructive equipment, do not venture far from the shore, selectively target fish according to time of year and abundances of fish and discard almost none of their catch (Chuenpagdee et al., 2006; Jacquet and Pauly, 2008; Chuenpagdee, 2012).

Small-scale fishers appear to be impacted by the depletion of fish populations, as well as by industrialized fishing practices, which intercept fish before they reach the inshore waters where these fishermen usually fish (Thomson, 1980; Berkes, 1985; Clover, 2008). Policies aiming to manage overfishing tend to focus on the regulation of the fishing effort through reducing the small-scale fishing fleet, reflecting the belief that large-scale fishing is the main supplier of fish to markets (Jacquet and Pauly, 2008; Preikshot and Pauly, 2008; European Commission, 2008). Sustainable use measures such as ecolabeling and management policies are also designed in a way that benefits industrialized fishing (Jacquet and Pauly, 2008). Further, small-scale fisheries are often at a disadvantage due to their remoteness and isolation, reduced infrastructure, and lack of access to decision-making processes, and resulting political marginalization (Chuenpagdee et al., 2006; Ponte et al., 2007; Panagopoulou et al., 2007; Jacquet and Pauly, 2008; Clover, 2008).

Today, 84% of fish stocks in the Mediterranean are considered overexploited (Colloca et al., 2013) and the intensive fishing practices continue to exert pressure on Mediterranean marine ecosystems (Tudela, 2004; Sacchi, 2008) and depleting fish stocks (Bearzi et al., 2006; Clover, 2008). Meanwhile by-catch, defined as the unintended capture of non-target species on fishing gear, has become a significant fisheries management issue (Hall et al., 2000; Soykan et al., 2008). By-catch is also a serious challenge for the conservation of many large marine vertebrate species such as sharks (Ferreti et al., 2008), cetaceans (Bearzi, 2002; Bearzi et al., 2006; Frantzis, 2007), monk seals *Monachus monachus* (Karamanlidis et al., 2008) and sea turtles (Lewison et al., 2004; Wallace et al., 2008; Casale and Margaritoulis 2010; Lewison et al., 2014).

In the Mediterranean, the total number of incidental captures of sea turtles in fishing gear has been estimated at 130,000 - 150,000 per year, the majority of which are loggerhead turtles (Lewison et al., 2004a; Lewison et al.,2004b; Camiñas, 2004; Casale, 2008; Wallace et al., 2010). It is estimated that small-scale fisheries are responsible for 62,000 sea turtle captures/year in the region. Despite the fact that this number represents 40-45% of the total captures, the mortality rate for by-caught turtles in small-scale fisheries is estimated at 26,500 individuals, a disproportionate 60% of the total estimated for the region (Casale, 2011). This can be explained by gear types used by small-scale fishermen, such as gill nets that include set nets, drifting nets, and trammel nets that cause high mortality rates (up to 70%) probably due to long soak durations (Casale, 2008). In addition, incidents of intentional sea turtle killings have been noted in Greece, Tunisia, Turkey and Egypt (Panagopoulou et al., 2007; Casale, 2008; Nada and Casale, 2011). While individual small-scale fishers may only catch a few turtles a year and may thus consider that these captures are insignificant, the large size of the small-scale fleet suggests that such by-catch may seriously impact sea turtle populations in the region (Soykan, 2008; Casale, 2011). Thus, it may represent a conservation priority for loggerhead turtles in the region.

Rethymno (longitude: 24° 32' 3" E; latitude: 35° 12' 52" N) is situated on the Northern coast of the island of Crete. It hosts the third largest nesting aggregation of loggerheads in Greece, accounting for approximately 9% of the total nesting effort recorded in the Mediterranean (Margaritoulis et al., 2003; Margaritoulis 2005; Margaritoulis and Panagopoulou, 2010) (Figure 1.1). The nesting site stretches east of Rethymno for 12 km, of which 10.8 are suitable for egg-laying. The annual recorded nesting effort ranges from 166 to 516 nests averaging 324 nests per year (Margaritoulis and Panagopoulou, 2010). Rethymno has been experiencing severe declines in nesting activity over the last decade (Margaritoulis et al., 2009; 2010), the exact causes of which remain unidentified even though it is suspected that interactions with fisheries and the resulting mortality may be a major contributing factor (Casale, 2011).

Its regional importance for Mediterranean turtles was a major contributing factor to the inclusion of 80% of the site in European Union’s Natura 2000 Network as a Site of Community Importance (SCI, Index Code GR4330004). The site includes a marine zone offshore of Rethymno that encompasses the 50m isobaths. This marine protected area is characterized by EU priority marine habitats that include *Posidonia oceanica* beds

(Habitat Type 1120), and reef formations (Habitat type 1170) (Data: HMCR, 1997) and is inferred to be the internesting habitat for the loggerhead turtles nesting in the area.

Under European law, Greece has to design and implement management measures for the NATURA 2000 site. Current management proposals only cater to the terrestrial habitat of the population (Panagopoulou et al., 2003). The effective conservation and management of any protected species requires knowledge of key factors regarding its habitat preferences and high-use areas. Therefore, the main objective in this study was to provide scientific information necessary to address related gaps in our knowledge of loggerheads nesting in Crete in order to contribute to the compilation and implementation of effective management policies for the marine area of the NATURA 2000 site. Specifically, I aimed to answer key questions regarding the behavior of sea turtles while in the area. The following paragraphs identify the questions, and the chapters that address them.

One of the main factors contributing to the failure of Marine Protected Areas (MPAs) is the insufficient original planning such as excluding critical habitat for the species it was created to protect (Agardy et al., 2011). For example, the National Marine Park of Zakynthos, which hosts the largest rookery for loggerhead turtles in the Mediterranean (Margaritoulis et al., 2003; Casale and Margaritoulis, 2010), is inadequately designed because sea turtles occupy an area outside of the strict protection zone, where the least amount of regulations are in effect and where they turtles remain relatively unprotected. (Zbinden et al., 2007; Schofield et al., 2009; Schofield et al., 2010). Therefore, in **Chapter 2** of this thesis, I used satellite telemetry and ultrasonography data in order to identify key information relevant to the internesting behavior of loggerhead turtles. This includes the internesting interval and estimated clutch frequency. I also attempt to define the internesting habitat used by this population comparing it to the boundaries of the protected area.

The habitat used by sea turtles is also a human high-use area and this increases anthropogenic pressure on this population. Rethymno is quite heavily developed for tourism, and there are several watersports operators set up along the beach. There is also significant small-scale fishing activity, with local fishers using predominately static nets and trammel nets. Some gear, trammel nets in particular, are reported to be left soaking for days at a time, increasing the risk of accidental capture and mortality of turtles. In **Chapter 3** of this thesis, I discuss satellite telemetry and Time-Depth data logger data to assess the usage of the vertical water column by loggerhead turtles nesting in Rethymno during the internesting interval. These data are important in assessments and mitigation efforts for such anthropogenic pressures.

The designation of a protected area is a powerful tool for the conservation of an important habitat for marine species, however it is only a first step. In many cases, MPAs have been met with scepticism and have even been rejected by affected stakeholders (e.g. Halpern and Warner, 2003; Jentoft et al., 2012). Fishermen and their families are central to local community structures, especially in Greek islands (Tzanatos, 2005; Tzanatos, 2006). Small-scale fishermen based in Rethymno are important stakeholders in the area and therefore likely to be affected by any management measures related to the Rethymno marine area. For this reason, in **Chapter 4** of this thesis I present data and analyses of responses collected via semi-structured interviews. I used a questionnaire to investigate fisher perceptions of impact of sea turtles on them and their profession. I also asked about their recommendations of possible solutions, and their views and opinions of protected areas.

Finally, in **Chapter 5,** I compile the major findings from these project components into a discussion of recommendations for the management of the NATURA 2000 site, offering suggestions for future research.

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Figures

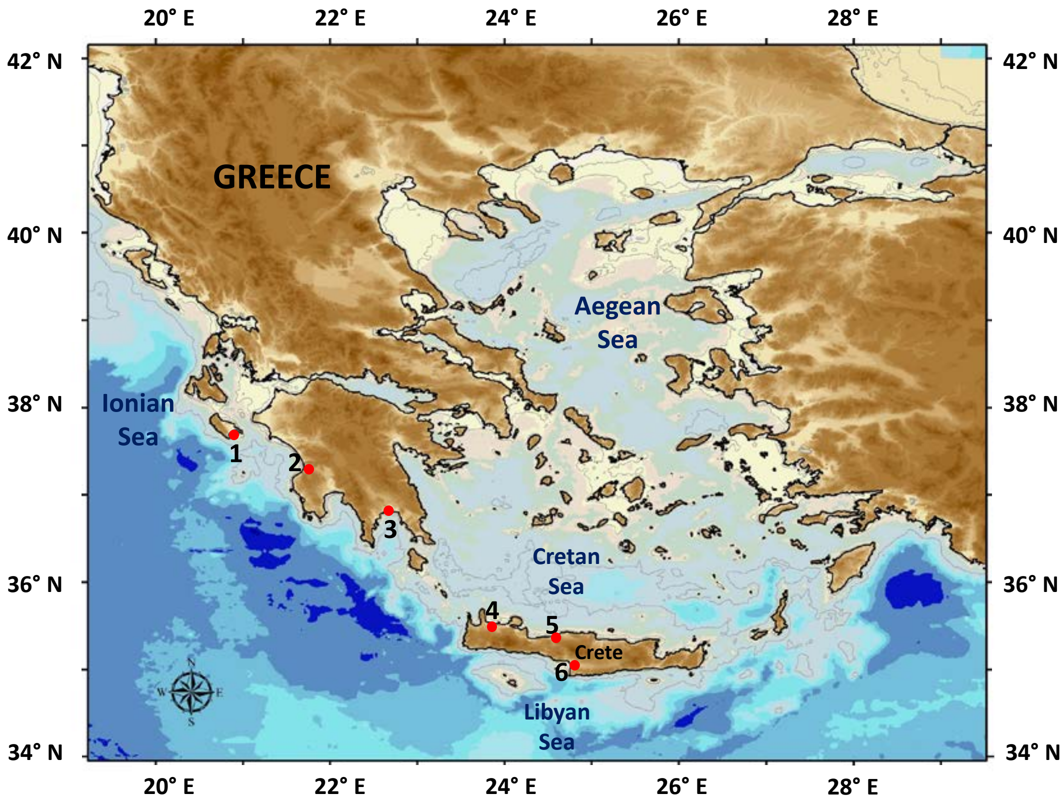

Figure 1.1. Major nesting sites for loggerhead turtles in Greece. 1. Zakynthos (1,244 nests per season). **2.** Southern Kyparissia Bay (621 nests per season). **3.** Lakonikos Bay (197 nests per season). **4.** Chania Bay (94 nests per season). **5**. Rethymno (324 nests per season). **6.** Messara Bay (51 nests per season). (Margaritoulis and Panagopoulou, 2010).

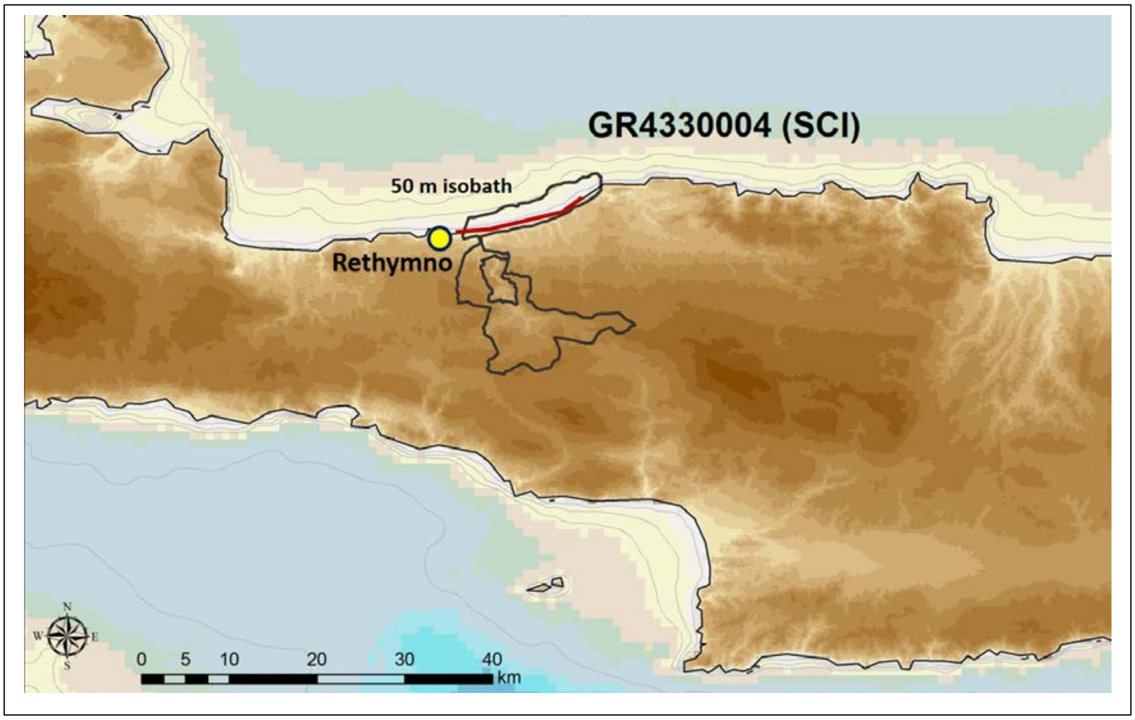

Figure 1.2. Map of Natura 2000 site (Site of Community Importance - SCI). Red line indicates the core nesting area for loggerhead turtles.

Chapter 2: Internesting behavior of loggerhead turtles, *Caretta caretta*, nesting in Rethymno, Greece: Fecundity, Movements, and Strategies.

Introduction

Sea turtles spend almost all of their lives within the marine environment despite relying only on terrestrial habitats for their reproduction. In addition, they engage in long-distance migrations covering thousands of kilometers (Plotkin, 2003). These migrations are difficult to study because sea turtles swim over vast areas and spend much of their time underwater. In recent years, with the advances of modern technology and the development of new bio-logging techniques, many questions on sea turtle ecology, behavior and physiology are being answered. For example, satellite telemetry studies have provided insights on the sea turtle distribution, identified critical habitats and migratory routes, and highlighted behavioral patterns during foraging and/or overwintering (reviewed in Godley et al., 2008; Bailey et al., 2008; Hart et al., 2015) or during the “lost years” (Casale and Mariani, 2014; Mansfield et al., 2014).

All seven species of sea turtles share similar life-cycle characteristics, particularly when it comes to their reproduction (Miller, 1997; Bolten, 2003). Reproductively active male and female turtles leave their foraging areas and arrive to their nesting beaches several weeks before nesting begins (Limpus et al., 1992; Miller, 1997; Musick and Limpus, 1997; Schroeder et al., 2003; Plotkin 2003). Often courtship and mating occur close to the nesting grounds or on the way to the mating areas (Pritchard, 1982; Eckert and Eckert, 1989; Plotkin, 2003; James et al. 2005; Rostal, 2007; Morreale et al., 2007).

Meanwhile, in the few months prior to nesting, vitellogenesis occurs as pre-vitellogenetic ovarian follicles mature and increase in size (Rostal, et al., 1998; Hamann et al., 2003). In the period just prior to courtship and mating, pre-ovulatory vitellogenic follicles are fully developed in the ovary (Rostal, 2007). Soon after the first successful mating event, the first ovulation for the season occurs (Rostal, 2005). Follicles are ovulated from the ovaries moving to the oviduct (Owens, 1980; Rostal et al., 1996; Rostal, 2015), where fertilization occurs (Hamann et al., 2003). As the ovum progresses through regions of the oviduct, it is surrounded by an albumin layer and the shell membrane and the egg shells are formed (Owens, 1980; Rostal, 2007; Rostal, 2015).

Atresia occurs when some follicles are not developed into shelled eggs during ovulation and the oocyte nutrients contained in the yolk are reabsorbed by the turtle (Rostal, 2015). Atretic follicles first exhibit a “cat-eye” appearance characteristic for sea turtles, but then their shape becomes less spherical, shrinking in size as they degenerate, eventually leaving a small scar in the ovary (Rostal, 2015). The functional role and the drivers for atresia are poorly understood, however it is possible that atretic follicles serve as a means to compensate for energy invested into migration and oviposition in fasting turtles (Hamann et al., 2003; Rostal, 2007; Perrault et al., 2014).

Once ovulation and shelling are complete, the female proceeds to lay her clutch. Female sea turtles deposit several clutches at two-week intervals over the nesting season, so ovulation is repeated several times in one season, with ovulation and shelling occurring probably within 48 hours after each clutch has been laid (Owens, 1980; Rostal, 2007). As the nesting season progresses, there are pre-ovulatory follicles, atretic (reabsorbing) follicles and fully-shelled eggs in the ovary; however these decrease in number and the ovary decreases in size as the female nears the end of the reproductive period (Rostal, 2007; Rostal, 2015).

The period between two successive nesting events is defined as the internesting interval (Limpus, 1985; Houghton et al., 2002). Clutch frequency is defined as the number of nests laid per female turtle per season. For loggerhead turtles, *Caretta caretta*, clutch frequency is estimated at 1 - 7 nests per season (average: 3.5) with an internesting interval ranging from 9 – 21 days (summarized by Dodd, 1988; and by Schroeder et al., 2003). However, clutch frequency is very likely underestimated as nesting events by individual turtles may remain unobserved because surveys may not occur along the entire nesting site, or the spatial spread of the nests that may be outside the limits of the monitored area (Le Buff, 1990; Schroeder et al., 2003; Shamblin et al., 2014). Recent satellite telemetry studies support the hypothesis that the number of nests deposited over a single reproductive period is underestimated for many loggerhead populations and increase the clutch frequency to 5 nests per season (Rees et al., 2010; Tucker et al., 2010). In the Mediterranean, where some of the most important rookeries are located at relatively high latitudes (above 35°N), clutch frequency for loggerheads is estimated at 1 to 3 nests with an internesting interval of 10 – 24 days (Margaritoulis, 1983; Broderick et al., 2002; Margaritoulis et al., 2003; Turkozan and Yilmaz, 2008). However, Zbinden et al. (2007) conducted a satellite telemetry study on Zakynthos Island in Greece that strongly suggests that clutch frequency is at least four nests per season.

Once the breeding season is complete, females return to their foraging/overwintering areas and it is several years before they have replenished their energy reserves and are ready to nest again (Miller, 1997; Hamman et al., 2003; Rostal, 2015). In recent years, an increasing number of studies has provided valuable information on the post nesting movements and migratory routes undertaken by sea turtles (reviewed by Godley et al., 2008; also see Luschi and Casale, 2014 for a Mediterranean-specific review). However, there are fewer studies on the internesting behavior of turtles, mainly due to the reluctance of researchers to attach expensive transmitters when there is a high risk of loss or malfunction due to mating, resting behavior under rocky formations, nesting, etc. (Godley et al., 2008). The studies that are available worldwide provide valuable insights into the internesting behavior of turtles and they indicate that during the internesting interval, sea turtles generally spend most of their time at specific areas in close to the shore, although different behaviors occur between species and between different populations of the same species. Leatherback turtles, *Dermochelys coriacea*, can use extensive areas during the internesting interval that may cover several hundreds of kilometers (e.g. Eckert, 2006; Georges et al., 2007; Hittipew et al., 2007; Witt et al., 2008; Shillinger et al., 2010). Green turtles (*Chelonia mydas)* often remain in a specific area close to the nesting beach (Pacific and Indian Ocean: Dizon and Balazs, 1982; Kittiwattawong et al., 2002; Craig et al., 2004; East Pacific: Blanco et al., 2013; Mediterranean: Fuller et al., 2008). Green turtles nesting on Ascension Island gather in specific areas where mating occurs (Carr et al., 1974) and green turtles nesting in the western Caribbean use areas more than 130 km away from the nesting site (Troëng et al. 2005a). In the Cayman Islands green turtles use oceanic habitats 197 km away (Blumenthal et al., 2007). Hawksbill turtles (*Eretmochelys imbricata*) utilize habitats in close proximity to the nesting beach (e.g. Troëng et al. 2005b; Marcovaldi et. al., 2012; Walcott et.al, 2012) as do Kemp’s ridleys (*Lepidochelys kempii*) (Seney and Landrey, 2008; Shaver and Rubio, 2008). Olive ridleys (*Lepidochelys olivacea*) remain in close proximity to their nesting area (Whiting et al., 2007) but also travel to resting areas 200 km away (Hamel et al., 2008).

Loggerhead turtles exhibit a similar mix of internesting behavior. For the most part, they remain in the vicinity of their nesting site (e.g. Australia: Limpus, 1985; Limpus and Limpus, 2003; Cyprus: Fuller et al., 2008; Southeastern USA: Hart et al., 2010; Brazil: Marcovaldi et al., 2010; Oman: Rees et al., 2010). However, some loggerhead turtles utilize oceanic habitats as far as 135 - 200 km away from the original nesting site, performing “oceanic loops” before returning for their subsequent nest (Blumenthal et al., 2007; Rees et al., 2010). In the Mediterranean, loggerhead turtles nesting on Zakynthos Island spend the majority of their time within Laganas Bay where the main nesting beaches lie. However, a few depart the nesting area between successive nesting events, travelling as far as 200 km away before returning to lay another clutch (Zbinden et al., 2007; Schofield et al., 2009; Schofield et al., 2010).

The effective conservation management of any protected species requires knowledge of key ecological processes regarding its habitat preferences and high-use area use within such important sites such as nesting areas. There is a need to spatially define the internesting habitat to ensure that sea turtle populations are effectively protected at a time when they are vulnerable to anthropogenic disruptions. Rethymno on Crete hosts the third largest nesting aggregation of loggerheads in Greece, accounting for approximately 9% of the total nesting effort recorded in the Mediterranean (Margaritoulis et al., 2003; Margaritoulis 2005; Margaritoulis and Panagopoulou, 2010). Its regional importance for Mediterranean turtles was a major contributing factor to the inclusion of

80% of the site in European Union’s NATURA 2000 Network. Under European law, Greece will have to design and implement management measures for the site, including the marine area adjacent to the nesting beach that extends up to the 50 m isobath. In this study, I used satellite telemetry and ultrasonography to identify key information relevant to the conservation of the loggerhead turtle population nesting on Rethymno, Greece. Specifically, I used satellite transmitters to define the internesting habitat and to assess nesting strategies exhibited by this population. I also used ultrasonography to assess other facets of reproductive behavior such as clutch frequency. I hypothesized that loggerhead turtles nesting in Rethymno remained in close proximity to the nesting beach during the internesting interval and that their total reproductive output did not differ from that of other loggerhead populations in the Mediterranean. This study was unique in that it took place over the course of an entire reproductive season and that it combined satellite telemetry and ultrasonography to describe the behavior of loggerhead turtles during the internesting interval. The findings in this study will help with the compilation of management policies for the Rethymno NATURA 2000 site.

Materials and Methods

The study took place during the 2010, 2011 and 2012 nesting seasons in collaboration with ARCHELON, the Sea Turtle Protection Society of Greece. Using a combination of direct observations, ultrasonography and satellite transmitters, I collected data on clutch frequency and the diving behavior during the internesting interval of 20 female loggerheads nesting in Rethymno, Crete. From these three seasons I also calculated the internesting interval. In addition, I used satellite telemetry data from post-nesting turtles that remained resident along the island during 2010 (n = 1) and 2011 (n = 3) to identify other important habitats for turtles on Crete beyond the nesting season.

Between the months of June and August, my research team and I patrolled the easternmost 2.5 km of the Rethymno site at night in search of nesting loggerhead turtles. I selected this section of the beach because it exhibits the highest nest density for the Rethymno site yearly (ARCHELON, unpublished data). When I encountered a nesting female, I waited until she had finished laying her eggs and started covering the egg-chamber at which point I measured the curved and straight carapace length (CCL, SCL) and curved and straight carapace width (CCW, SCW). Next, I applied two external flipper tags for the ARCHELON monitoring project. These tags also identified individual turtles included in my study. While the turtle continued to cover the egg chamber, I performed an ultrasound examination to assess if the turtle had enlarged follicles remaining in her ovary. The presence of such follicles suggested that the female would probably return in approximately two weeks to lay another clutch and therefore was suitable for my study. Once additional clutches were observed, I attached the satellite transmitter to the carapace. Several days later, when I re-encountered the turtle, I performed another ultrasound, retrieved the attached transmitter and if I observed more enlarged follicles in her ovary I deployed a new transmitter and continued to study her.

Ultrasound examination

In order to assess the turtle's reproductive status, I used a real-time portable ultrasound scanner following the method developed by Rostal et al., (1990) and adapted by Blanco et al., (2012). I used a Sonosite 180 Vet Plus (Sonosite, Inc, Bothell, Washington) with a C60/5-2 MHz transducer (display depth: 6 cm), digitally storing the ultrasound images resulting from the examination on a laptop computer. Prior to examination I coated the probe with acoustic coupling gel (Aquasonic® 100, Parker Laboratories Inc., New Jersey) to maintain contact and enhance the quality of the imaging. I visualized each ovary and oviduct by placing the transducer in the inguinal area, on the soft-tissue lateral to the plastron and cranial to the femurs of both the right and left sides of the turtle and orienting it towards the contralateral flipper. This acoustic window provided the optimal position for imaging of the turtle's reproductive structures (Valente et al., 2007). This non-invasive process took approximately 5 minutes for each scanned turtle.

Deployment of satellite transmitters

I monitored internesting and post-nesting movements of turtles by deploying 17 Mk10-PAT and 4 Mk10-AF with Fastloc® capabilities (Wildlife Computers, Redmond, Washington) on 21 females (Turtle 01 – Turtle 20 and Turtle A). Internesting movements and behavior were observed for 20 of these turtles that were reproductively active and likely to return in approximately two weeks to lay another clutch (Table 2.1). In addition, I collected data on the movements of one post nesting turtle from the 2010 season and three postnesting movements from the 2011 season that remained resident along the island after they had completed their nesting season (Table 2.2.).

To increase buoyancy, I modified the Mk10-PAT transmitters to ensure that the device would be in an upright position as the turtle came to the surface to breathe, thus facilitating transmission of data to the Argos System (Blanco et al., 2012; Patel, 2013). I encased the transmitter in a hydrodynamically shaped cone made of syntactic foam taking care to keep the sensor and antenna areas unaffected. The modified transmitters weighed approximately 115 g and had a buoyancy of about 36 g (Blanco et al., 2012; Patel, 2013). The transmitters' hydrodynamic shape and the minimal buoyancy, combined with its position in relation to the body of the turtle allowed for the transmitter to remain in the turtle's slip stream as she swam greatly reducing drag (Logan and Morreale 2003; Blanco et al., 2013; Jones et al., 2013).

Attachment method

For the deployment of the satellite transmitters, I followed a procedure designed by Standora et al. (1982), further developed by Morreale et al. (1996), Morreale (1999), and modified by Blanco et al., (2013). This technique entailed attaching the transmitter on a tether that trailed the turtle as it swam (Figure 2.1). After the turtle finished nesting onshore, I first I cleaned the area on one of the two supracaudal scutes using 70% alcohol to remove all traces of sand and disinfect the area where the transmitter would be attached. Then I made a small circular incision (5 mm) at a distance less than 2 cm from the outer edge of the scute. I immediately disinfected the incision using a Povidone-iodine based topical antiseptic solution. Next, I completed the assembly of the tether that would be used for securing the transmitter on the carapace using 180 kg test monofilament fishing line. I subsequently inserted sterilized tubing (3.2 mm inside diameter, 6.4 mm outside diameter and 1.6 mm wall thickness) through the incision. The surgical tubing prevented direct contact between the tether and the carapace, minimizing abrasion. Then I inserted the monofilament fishing line through the surgical tubing, through a soft polyethylene button on the ventral side of the carapace and back through the tubing. The fishing line also passed through another small button on the dorsal side of the carapace. The soft buttons were made of high-density polyethylene with smoothed edges, prevented contact between the elements of the tether and the carapace and spread the force of the transmitter pulling on the carapace, limiting the impact of the attachment. To secure the satellite transmitter to the tether, I used two double-barreled 2.2 mm diameter crimps one on each side of a swivel to allow for rotational movement of the satellite transmitter. The crimps and swivels used were made of corrodible materials with the intent that they would break away within a year or less. The total length of the tether ranged from 15 – 25 cm and was adjusted to ensure that it would not interfere with the movement of the front or rear flippers of the animal. The entire process, which lasted from 7 to 10 minutes, entailed minimal restraint of the turtle and was designed to alleviate stress levels. Along with the lower level of drag as compared to objects directly attached onto the anterior areas of the carapace (Logan and Morreale, 1994; Watson and Granger, 1988; Jones et al., 2013), the reduced handling of the turtle was considered a distinct advantage.

Estimated Clutch Frequency (ECF)

For my study, I defined the Observed Internesting Period (OIP) as the number of days elapsed between two successful nesting events. I calculated the mean OIP by averaging the OIP for all turtles for which I had OIP information (n = 19), excluding cases where the OIP was greater than 23 days, as these implied an occurrence of an unobserved nesting event (Margaritoulis, 1983; Schroeder, 2003; Margaritoulis et al., 2003).

I used three different approaches to calculate the Estimated Clutch Frequency (ECF) for loggerhead turtles nesting in Rethymno from a subset of females (n = 18) studied in 2011 for which I could apply all three of the following methods. First, I determined observed clutch frequency (OCF) from direct observations by counting the number of successful nesting events observed for each individual turtle. Considering that a non-nesting emergence is indicative of imminent nesting, (Margaritoulis, 1983) and that internesting intervals longer than 23 days suggest a missed nesting event, I calculated ECF_{OB} by using the method applied by Reina et al., 2002:

$$ECF_{OB} = (\text{Date } 2 - \text{Date } 1) / OIP + 1$$

Where:

Date 1 = Day of 1st observation of the turtle

Date 2 = Day of last observation of the turtle

In an independent method, I calculated ECF through ultrasound examinations (ECF_{US}) by interpreting ultrasound images to assess the reproductive status of the female (Figure 2.2). Following guidelines established by Rostal et al. (1990, 1996) and further explored by Blanco et al. (2012) as well as personal communication with Dr. Robert H. George, I assigned ovaries into one of the following four categories: early ovulatory (mature vitellogenic follicles ~3 cm, full coelomic cavity, absence of degenerating atretic follicles), intermediate ovulatory (mature vitellogenic follicles, full coelomic cavity, degenerating follicles (> 7mm) present), late ovulatory (coelomic space, several vitellogenic follicles present, atretic follicles also be observed) and depleted (empty coelomic cavity, previtellogenic follicles present, interior structures such as intestinal loops and/or atretic follicles observed). When ovaries were assessed to be “intermediate ovulatory” in a female encountered for the first time for the season, I added one clutch to ECF_{OB} assuming she had probably produced at least one clutch before then. Similarly, if I observed more than 5 – 6 follicles in each ovary during the last encounter for the season, I added one clutch to ECF_{OB} because that female would probably return for at least another nest. Therefore:

$$ECF_{US} = \Phi_1 + ECF_{OB} + \Phi_2$$

Where:

$\Phi_1 = 1$ (if ovary was assessed as intermediate ovulatory at time of 1st observation)

$\Phi_2 = 1$ (if more maturing follicles where observed at time of last observation)

In the third method, I used satellite transmitters to help determine when nesting occurred. However, due to the specifications of the Mk10 transmitters used for this study, I was not able to apply all of the criteria used by Tucker (2010) to determine possible turtle emergences and therefore estimate clutch frequency. While it was possible to estimate proximity of the female to the coastline, I could not obtain high quality signals when the female was on shore nesting. Therefore, ECF values through satellite telemetry (ECF_{SAT}) were based on the assumption that females left the nesting site very soon after the last nest was deposited (Plotkin and Spotila, 2002; Miller et al., 2003; Schroeder et al., 2003; Girard et al., 2009) and I used day of departure from the site as the main criterion on whether one or more clutches should be added to ECF_{OB}. Specifically, this value depended on the number of days between the last observed nesting event and the date of departure from the site; I added one or more clutches (# of days/OIP) to the total ECF_{OB} for that animal. For resident turtles, I used the 14th of August as the final day of the nesting season for that individual:

$$ECF_{SAT} = ECF_{OB} + (Date3 - Date2)/OIP$$

Where:

Date 2 = Day of last observation of the turtle

Date 3 = Day of Departure from site

Finally I combined information from all three approaches to estimate total ECF (ECF_{TOT}).

Satellite telemetry, Utilization distribution and Determination of High Use Areas

I set transmitters onto a 24 h on duty cycle limiting the number of transmissions to 52 per day and having unused transmissions carried over to the next day. Transmitters sampled, recorded and transmitted location data via the Argos Satellite-based System, which I downloaded daily and entered onto a database. I conducted all mapping and plotting of spatial data using the ArcGIS 10.1 geographic information system software

(ESRI 2012). For turtle locations, I used Argos location classes (LC) 3, 2, 1, 0, A, B and the GPS locations when available. I manually filtered out all improbable locations (e.g. those that were on land).

To identify areas used by sea turtles, I performed a Kernel Density Analysis using the Kernel Density Tool for ArcGIS. For the distribution of locations over time, I included one location per individual turtle per day, selecting the best location quality when more than one data points were available. The core areas were determined by 25, 50 and 95% Utilization Distribution (UD).

Using the Minimum Bounty Geometry tool, I constructed Minimum Convex Polygons (MCP) for each individual turtle to delineate the internesting habitat for the Rethymno nesting population. By overlaying the MCPs for each individual turtle, I defined High, Medium and Low Intensity Use areas: High Intensity = polygons occupied by ≥ 15 turtles; Medium Intensity = polygons occupied by 6 – 14 turtles; and Low intensity = polygons occupied by 1 – 5 turtles. Finally, I constructed MCPs using the data from the resident females (i.e. those that overwintered along the continental shelf around Crete) to define the expanded area utilized by this local resident population.

The study was approved by the Animal Care and Use Committee of Drexel University and conducted under ARCHELON’s research permit provided by the Ministry of Agriculture of Greece.

Results

Overall, I tracked a total of 21 turtles with satellite transmitters. In 2010, I deployed one transmitter on a female that I assessed had deposited her final nest for the season (Turtle A). In 2011, I deployed satellite transmitters on 20 females that were internesting (Turtles 01-20). Nine of those females were monitored for more than one internesting interval, because I replaced the transmitters when the turtles were re-encountered to download stored data. Thus in total, the satellite transmitters recorded location data from 37 internesting intervals for 20 different females, totaling 666 days of transmissions and 1,156 location points (Table 2.1). One transmitter (Turtle 06) stopped transmitting as the female was returning for her second nest. She was re-encountered on 27/07/2011, with signs of the device having physically been removed, probably by a person. A second transmitter, (Turtle 09) stopped emitting information half-way through the internesting interval, but the female was not encountered again, and I attributed malfunction of the device as the most likely cause for the stoppage. I continued to monitor turtles 12, 13 and 19 after the end of the egg-laying season because they remained resident along the island until their transmitter batteries were depleted.

Internesting habitats

During the internesting interval, most female turtles remained close to the nesting beach. Most individuals showed a preference for an area offshore, near the middle of the nesting beach, remaining within 20 km from the shore although it was not uncommon for them to swim up to 50 km off shore. These turtles returned after approximately two weeks to deposit another clutch within 5 – 10 km of the original nesting site (Figure 2.3).

In contrast, 5 females adopted a different strategy. These turtles departed the nesting site soon after observation, travelled along the coast to other locations on Crete, to distances up to 150 km away and remained there for periods exceeding the 13 – 19 day internesting interval reported for the species in the region (Margaritoulis, 1983; Broderick et al., 2002; Margaritoulis et al., 2003; Turkozan and Yilmaz, 2008). All of these turtles nested again but at different nesting beaches on Crete. In all of these turtles, the presence of follicles in their ovaries at the time of observation suggested that they had at least one more clutch to deposit before they concluded their egg-laying season. Turtle 13 traveled 75 km west of the site and remained in the marine area west of the city of Chania, which is another important nesting site for loggerhead turtles on the island. Turtles 02 and 12 traveled approximately 80 km east to Gouves, a location east of the city of Herakleion while Turtle 04 went a few kilometers further east resting within Mallia Bay. Turtle 19 left the site immediately after observation and traveled 150 km east offshore Mirabello Bay at Agios Nikolaos, Lasithi Prefecture (Figure 2.3).

By constructing Minimum Convex Polygons (MCPs) for each female, I was able to identify the internesting habitat utilized by all loggerhead turtles tracked in Rethymno, which covered an area approximately 4,240 km^2 encompassing almost the entire north coast of Crete, from Cape Rodopou, Chania Prefecture in the west to Mirabello Bay, Lasithi Prefecture in the East. By overlaying the MCPs of individual turtles I designated a High Intensity Use area used by 15 or more of the tracked turtles. This 28 km^2 area started in Adele (6 km east of Rethymno city) and extended east for 8 km. I also identified a 540 km^2 Medium Intensity Use Area, utilized by 6 – 14 turtles, that extended from Georgioupolis (30km west of Rethymno city) to 27 km east of Rethymno (Figure 2.4). These findings showed that the NATURA 2000 area only partially included the areas most likely to be utilized by the Rethymno turtles, indicating a substantial gap in the at-sea protection of the internesting habitat for this population (Figure 2.5).

Kernel Density analyses yielded Utilization Distribution (UD) areas of 25%, 50% and 90% (Figure 2.6). Similar to the results yielded by the MCPs, the internesting habitat covered almost the entire north coast of Crete, extending from Cape Rodopou (Chania Prefecture) in the west to Mirabello Bay (Lasithi prefecture) in the east. Notably, approximately 60% of the 25% UD areas extended outside the NATURA 2000 site, and included core areas west (Georgioupolis, 30km; Chania, 57 km) and east (Heraklion/Gouves , 80 km; Milatos, 100 km) of Rethymno (Figure 2.7).

As soon as the egg-laying season was complete, most turtles departed the nesting site. However, four females did not leave the island but instead remained resident in the waters around Crete. Turtle A in 2010 was tracked after she had deposited her final clutch for the season. By August 11th she had departed the site and traveled to Gavdos Island, located south of Crete where she remained until the transmitter stopped emitting signals 112 days later. After the end of the 2011 season, Turtles 12, 13 and 19 remained close to the area where they appeared to have deposited their final clutches. As for the internesting movements, I generated MCPs for the overwintering habitat for each female that remained resident on the island. In total, the overwintering habitat covered an area of approximately 3,560 km^2. For the most part the overwintering and internesting habitats overlapped, although Turtle A selected a completely different area south of Crete to overwinter. (Figure 2.6).

Estimated Clutch Frequency

I recorded internesting intervals from 19 turtles (2010 = 3; 2011 = 9; 2012 = 7) and a total of 28 internesting periods (2010 = 4; 2011 = 16; 2012 = 8). The Observed Internesting Period (OIP) was 15.2 ± 1.3 days (Mean ± SD, with a range of 13 – 19 days); In 2010, OIP was 14.0 ± 0.8 days; In 2011, OIP was 15.3± 1.1 days; and in 2012 OIP was 15.5 ± 1.6 days.

Observed Clutch Frequency was 2.1 ± 1.1 nests (mean ± SD). I derived Estimated Clutch Frequency from a subset of 18 females from the 2011 season. ECF_{OB} was 2.1 ± 1.1 (Mean ± SD) nests per female per season (mode = 1). Ultrasonography gave a more accurate estimation of ECF because it was possible to assess if the turtle had already produced one or more clutches at the time it was first encountered or if she had one or more clutches to deposit when I encountered her for the last time in the season. Thus, ECF_{US} was 3.3 ± 1.0 (Mean ± SD) clutches per turtle per season (mode = 4). The addition of satellite telemetry information also yielded a higher ECF than ECF_{OB} because I was able to add one or more nests based on the time spent in coastal waters before the female departed the area. The value of ECF_{SAT} was 3.2 ± 1.2 nests per female per season (mode = 3). The most accurate ECF estimation was achieved by combining all three values from the approaches yielding ECF_{TOT} = 3.6 ± 1.0 (Mean ± SD) nests per female per season (median = 3.5, mode = 4) (Table 2.3).

Discussion

Using satellite telemetry and ultrasonography I was able to describe key components of the internesting behavior of loggerhead turtles nesting at Rethymno, Crete.

Internesting Interval

The Observed Internesting Period (OIP) was 15.2 days, ranging between 13 and 19 days. Duration of the internesting interval was longer than in earlier reports (13.6 days, range 12 – 18) for Rethymno (Margaritoulis et al., 2003) but not substantially so. It was within the ranges reported for other rookeries in Greece located at latitudes above 35° such as Kefalonia Island (15.8 – 17 days) , Zakynthos (14.6 – 19.9 days) and Kyparissia Bay (15.2 – 19.3 days) (reviewed by Margaritoulis et al., 2003). The interval was also within the range reported for loggerhead turtles throughout the Mediterranean and at other rookeries across the globe, although it tended to be lower than for rookeries outside the Mediterranean, except Florida and the Southeastern USA: e.g. 16 days in Turkey (Turkosan and Yilmaz, 2008), 13.4 days in Cyprus (Broderick et al., 2002), 16.4 days in Oman (Rees et al., 2010), 15 days in Japan (Iwamoto et al, 1985; Nishimura 1994), 15 days in South Africa (Hughes, 1974) and 11 – 13 days in Florida and other locations in the Southeastern USA (e.g. Talbert et al., 1980; Frazer and Richardson, 1985; Addison, 1996; Hart et al., 2010; Tucker, 2010).

Although preparation of the subsequent clutch begins immediately after oviposition (Owens, 1980), the rate at which egg maturation occurs and consequently the duration of the internesting period appears to be temperature dependent as occurs for green and loggerhead turtles (Sato et al, 1998; Hays et al, 2002; Weber et al., 2011). Schofield et al., (2009b) and Fossette et al. (2012) hypothesized that loggerhead turtles nesting on Zakynthos actively seek warmer waters early in the season to help speed-up the egg maturation process leading to earlier oviposition. Loggerheads nesting in Kyparissia Bay do the same (Backof, 2013), with the internesting period getting shorter as the season progresses. The duration of the internesting interval at Rethymno suggests that Rethymno females occupy colder waters than loggerheads in the southeastern USA but warmer water than in Japan and South Africa. Key elements in internesting behavior for East Pacific leatherback turtles are influenced from one nesting season to the next by oceanographic conditions, and these may also affect other internesting parameters such as OIP (Shillinger et al., 2010).

Clutch Frequency

Using a combination of direct observations, ultrasonography and satellite telemetry, I found that Rethymno loggerheads deposited 1 – 6 nests per season and the total Estimated Clutch Frequency (ECF_{TOT}) was 3.6 nests/female with a modal value of 4. This estimate was higher than the 1.3 nests found for Greece (Margaritoulis, 1983), and was consistent with more recent findings where telemetry (Scott, 2006; Zbinden et al., 2007; Rees et al., 2010; Tucker, 2010; Weber et al., 2013), ultrasonography (Blanco et al., 2012) and capture-mark-recapture models (Rivalan et al., 2006) have provided higher ECF values than OCF values. If we take into account that the egg-laying season is longer by at least two weeks on the major nesting beaches of Zakynthos and Kyparissia Bay

(Margaritoulis and Rees, 2001; Margaritoulis, 2005; Panagopoulou, pers. observation), it is likely that ECF for these populations is higher and possibly comparable to the estimates of more than 5 nests in Oman (Rees et al., 2010) and Florida (Tucker, 2010). In a study by Zbinden et al. (2007) four loggerheads tracked by satellite transmitters in Zakynthos deposited three to four clutches even after being tagged well after the start of the egg-laying season, which may begin as early as May 18th in the area (Margaritoulis, 2005). Even accounting for the fact that sea turtles nesting activity may start asynchronously, those females probably had already laid at least one clutch at the time they were tagged, and the total number of nests they deposited for that season may have been as high as 7 nests.

Sea turtles are usually difficult to study at sea due to logistical and technological constraints. Therefore, for many areas, population abundances and trends are studied via data derived from nest counts and tagging programs on nesting rookeries (Heppell et al., 2003; Witherington et al., 2009; Bjorndal et al., 2010), even though such data are increasingly recognized as insufficient as they do not account for males, non- gravid females or other age classes of high reproductive value that are harder to study because they exclusively occupy marine habitats (e.g. Crouse et. Al, 1987; Heppell et al., 2003; Wallace et al., 2008; Bjorndal et al., 2010). For such estimates of abundance, clutch frequency is a key parameter and its accuracy is crucial in order to correctly assess the number of reproductively active females in a given season (e.g. Alvarado and Murphy (1999); Bjorndal et al., 2010)).

Alvarado and Murphy (1999) suggest that the total number of nesting females can be estimated by dividing the total number of nests by the known clutch frequency.

Consequently, to underestimate clutch frequency can have a substantial effect on estimations of reproductively active female turtles and this may have serious conservation implications. For example, in the case of Rethymno, to apply the ECF_{OB} from this study (2.1 nests) on the average of 324 clutches recorded in the area, (Margaritoulis and Panagopoulou, 2010), would lead to an overestimation of approximately 150 breeding females annually. The more accurate ECF_{TOT} derived from observations, telemetry and ultrasonography (3.6 nests) indicates that the annual number of nesting females is closer to 90, meaning that the nesting population in Rethymno and likely other areas may be substantially overestimated.

Site fidelity during internesting

Most of the turtles included in this study (n = 15) remained close to the nesting site during the internesting interval and returned after approximately two weeks to deposit another clutch within 5 – 10 km of the original site. In contrast, 5 females left the site and remained away longer than the previously reported internesting interval for the region (Margaritoulis, 1983; Broderick et al., 2002; Margaritoulis et al., 2003; Turkozan and Yilmaz, 2008). For all of these individuals, the presence of follicles in their ovaries indicated that they probably used these other locations as alternative nesting sites for at least one of their subsequent clutches. Moreover, these alternative sites include habitats suitable for egg-laying where diffuse nesting has been observed in the past (Margaritoulis and Dretakis, 1991).

Low site fidelity such as observed in 25% of these turtles has been observed in loggerhead turtles in the past (e.g. Lebuff, 1990). More recently, Scott (2006) found that

27% of loggerheads nesting in Georgia display low site fidelity, nesting up to 64.6 km away from the original nesting site, and Tucker (2010) showed that satellite-tracked turtles in Florida may lay their subsequent nest as far as 109 km away. Interestingly, he indicated that if the first clutch is omitted, the distance between successive clutches was shorter. Similarly a study of loggerhead turtles nesting in North and South Carolina and Georgia reported that some females displayed low site fidelity (Shamblin et al., 2014).

Low site fidelity during a single nesting season also occurs in other sea turtle species. Leatherbacks that nest on Sandy Point, St. Croix Island sometimes nest on Culebra Island, Vieques Island, and Puerto Rico (Keinath and Musick, 1993 and Boulon, et al 1996). Similarly, Hittipew et al. (2007) and Byrne et al. (2009) suggested that extensive movements of *Dermochelys coriacea* nesting in Indonesia and the Caribbean were indicative of site infidelity. In the Carribean, Blumenthal et al., (2007) commented that there may be a possible shift in nesting sites by green turtles in the Cayman Islands. Walcott et al., (2012) speculated that neophyte hawksbill turtles displaying low site fidelity was a possible reason for non-recovery of attached equipment. To explain this behavior, Richardson (1982) hypothesized that neophyte loggerhead turtles nesting in Cumberland Island in Georgia USA disperse further away than more experienced females. In Florida Keys neophytes also tended to disperse further from the original nesting site and Tucker (2010) hypothesized that "younger turtles spread risk in space but not in time". In my study, of the 5 turtles that shifted nesting locations intraseasonally, 2 had been previously tagged. Therefore while the "neophyte turtle" conclusion has some merit in that inexperienced turtles may try several sites within the same region before focusing their effort in a more specific area, it is insufficient to fully explain this behavior.

Variability in nest site selection is a key element in the evolutionary success of a species. Scattering of nest locations during the same season may be a bet hedging strategy that allows a population to survive adverse effects of storms and sea level rise (Fish et al., 2005). This mechanism is evident in the Mediterranean, where loggerhead turtles have formed a genetically distinct population originating from the Southeastern USA (Bowen et al., 1993; Bowen and Karl, 2007). In a recent study analyzing expanded mtDNA sequences from nesting rookeries in Greece, Turkey, Israel, Lebanon, Italy and Libya, Clusa et al. (2013) found that loggerhead turtles colonized the Mediterranean during the Pleistocene. The oldest rookery in the region is in Libya where loggerheads first established a population c.a. 65,000 years ago. Western Greece was colonized about 30,000 years ago. Libya, Western Greece and Eastern Turkey may have served as refugia during cold periods and served as stepping stones to recolonize the Mediterranean after the end of the glacial periods. The same study reports a possible second colonization event from West Atlantic populations dating back 15,000 years ago. Therefore, the low site fidelity that I observed in some loggerheads nesting at Rethymno may be indicative of a mechanism enabling sea turtle populations to establish new populations at alternate sites.

Internesting habitat

My results indicate that only a portion of the core areas frequented by internesting loggerheads in the waters of Crete is included in the marine NATURA 2000 site. This was indicated both by the Kernel Density Analysis and by the converged MCPs for individual turtles. One of the main reasons causing the failure of Marine Protected Areas (MPAs) is the insufficient original planning that may exclude critical habitat for the species it was created to protect (Agardy et al., 2011). Insufficient planning likely originated from lack of data on the behavior and habitat usage at the time. Several studies have shown that sites designed to protect sea turtles are insufficient because they do not include critical areas utilized by the turtles. For example, leatherback turtles nesting in Gabon spend 62% of their time outside the boundaries of the park designed for their protection (Witt et al., 2008). Similar findings indicated that designated protected areas in Guanacaste, Costa Rica, protect only part of the internesting area utilized by the critically endangered East Pacific leatherback turtles (Shillinger et al., 2010). In Queensland Australia, almost 90% of the loggerhead turtles nesting within the Woongarra Marine Park are vulnerable to trawling activity because they swam outside the boundaries of the park (Tucker et al., 1995). In Greece, the marine area of the National Marine Park of Zakynthos, which hosts the largest rookery for loggerhead turtles in the Mediterranean (Margaritoulis et al., 2003; Casale and Margaritoulis, 2010), is inadequately designed because sea turtles occupy an area outside of the strict protection zone, where the least amount of regulations are in effect (Zbinden et al., 2007; Schofield et al., 2009; Schofield et al., 2010).

Sea turtles spend a relatively short period of their time in internesting habitats, however, this is a time when they are particularly vulnerable to anthropogenic pressure because they are near the coast that is heavily used by humans (eg Richardson et al., 1978; Tucker et al., 1995; Lutcavage et al., 1997). This is further exacerbated by the fact that they aggregate in their internesting habitats in great numbers. My findings demonstrated that the area used by loggerhead turtles nesting in Rethymno exceeds the protected area. Although the internesting habitat may vary across seasons, (Schofield et al., 2009; Shillinger et al., 2010), and there is a lack of information on the use of the area by male loggerhead turtles, there is a clear need to revisit the designation of the protected area before making any decisions on management policies.

The combined Minimum Convex Polygons created for each female converged to indicate a High Intensity Use Area utilized by most of the turtles included in the study (15 – 19 individuals) surrounded by a Medium Intensity Use Area utilized by 6 – 14 individuals. There is a general dearth of information available on the types of microhabitat present at the internesting sites for sea turtles. Hochscheid (1999) inferred that green turtles nesting in Cyprus forage while resting in areas with *Zostera marina*, *Cydomocea nodoza* and *Halophila stipulata* sea grasses. Limpus and Reed (1985) observed an internesting loggerhead in Heron Island resting head first into a cavity at the base of a coral wall. Similarly, loggerhead turtles nesting in the Florida Keys frequent areas with seagrass, rubble, sand and reefs although it is not known how these habitats are utilized (Hart et al., 2010). Hawksbill turtles nesting at Barbados occupy coral reef formations with hard corals, gorgonians and erect sponges, utilizing ledges in between the corals to rest (Walcott et al., 2014).

The marine protected area offshore Rethymno (NATURA 2000 site) is characterized by EU priority marine habitats that include *Posidonia oceanica* beds (Habitat Type 1120), and reef formations (Habitat type 1170) (Data: HMCR, 1997). I corroborated this information by conducting an on-site survey by boat on 6 July 2011

(Panagopoulou and Morreale, pers. observation). In the High Intensity Use area, the sea floor was characterized by sandy areas, patches of *Posidonia oceanica* sea grass and rocky formations with ledges. Thus, loggerheads nesting at Rethymno show a preference for the High Intensity Use Area because of the diversity of microhabitats available to them, which allows them to rest in relatively shallow waters hiding under ledges, helping them to conserve energy and to avoid predators and where "hopeful" males seek to mate.

Crete serves as an overwintering area for a portion of the Rethymno nesting population. That is one of three overwintering strategies (Patel, 2013), in which 4 satellite-tracked females remained resident along the island. Residency of turtles near the nesting site occurs in other turtle populations in the Mediterranean (eg. loggerheads, Schofield et al., 2013; green turtles, Stokes et al., 2015), however in both cases residence close to the nesting site was by a single individual, despite the large sample (Schofield et al., 2013: n = 38; Stokes et al., 2015: n = 34). In this study, I observed the behavior in a larger proportion of individuals and it occurred regularly across seasons (2010: n = 1; 2011: n = 3), indicating that this was an important nesting strategy of the population. There are some benefits associated with remaining close to the nesting site instead of undergoing migrations over hundreds of kilometers. It is possible that some females may trade-off long migrations for the opportunity to nest close by with minimal migration costs and in consecutive seasons thus increasing their total reproductive output. It is also possible that females, by remaining resident, may benefit from getting "first choice" of males migrating to the mating areas adjacent to the nesting habitats before their conspecifics arrive on site. In any case, these findings have important conservation implications as they suggest that the neritic habitats around Crete are used by sea turtles year-round and warrant management on a 12 month basis.

Conclusions

This study highlighted important components of the internesting behavior of loggerhead turtles nesting at Rethymno. The higher ECF calculated using three observation methods suggests that estimates of the number of nesting females in the region are overestimated. The low site fidelity exhibited by Rethymno turtles indicates that the population is not totally restricted to this site, but is more dispersed across the island. This suggests that the observed decline in nesting activity in Rethymno (Margaritoulis et al., 2008; Margaritoulis et al., 2009) may reflect a shift in nesting habitat rather than an actual decline in population. Consequently, it is important that the island be re-surveyed for an updated overview of Crete nesting activity. My findings show that management measures for loggerhead turtles within the Marine NATURA 2000 site are insufficient because the MPA only partially protects areas of high use by internesting females. Therefore, the boundaries of the protected area should be redrawn based on the high and medium use areas of turtle activity during the internesting season. Finally, because the turtles use a much larger area of Crete for nesting and overwintering than previously known, protection measures should be expanded to include all of the areas used by the turtles.

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Tables and Figures

Table 2.1. Summary data for the 20 satellite-tracked turtles. All turtles were assessed to be internesting. ‡ indicates turtles that remained resident on Crete after the egg-laying season was completed. Each line in table represents one deployment. For turtles with fitted with a transmitter more than once, days of observation, number of location points and total intervals observed are summarized in the last entry for the particular animal. Number of intervals corresponds to the estimated intervals covered during the observation period.

TURTLE ID	CCL (cm)	Deployment #	Date Deployed	Date Retrieved	Date of estimated departure from site (or of last transmission)	Days of observation	Total # of location points	Number of Inter-nesting Intervals
Turtle 01	78.5	I	01/06/2011	16/06/2011				
		II	16/06/2011	30/06/2011				
		III	30/06/2011		24/07/2011	53	78	3
Turtle 02		I	05/06/2011		18/07/2011‡	43	12	2 - 3
Turtle 03	71.0	I	06/06/2011	22/06/2011				1
		II	23/06/2011	08/07/2011		31	60	1
Turtle 04	81.0	I	07/06/2011	10/07/2011				
		II	10/07/2011		30/07/2011	53	198	3
Turtle 05	82.0	I	08/06/2011	23/06/2011				
		II	24/06/2011	08/07/2011				
		III	10/07/2011		14/08/2011	64	105	4
Turtle 06	90.0	I	11/06/2011		22/06/2011	11	24	1
Turtle 07	85.0	I	12/06/2011	28/06/2011	No transmitter	16	20	1
Turtle 08	85.0	I	13/06/2011	26/06/2011				
		II	28/06/2011	12/07/2011				
		III	12/07/2011	25/07/2011	27/07/2011	40	83	3
Turtle 09	86.0	I	16/06/2011	01/07/2011				
		II	03/07/2011		16/07/2011	28	33	2
Turtle 10	82.0	I	18/06/2011	03/07/2011				
		II	03/07/2011	16/07/2011	No transmitter	28	46	2

Table 2.1. (Continued)

TURTLE ID	CCL (cm)	Deployment #	Date Deployed	Date Retrieved	Date of estimated departure from site (or of last transmission)	Days of observation	Total # of location points	Number of Inter-nesting Intervals
Turtle 11	84.5	I	19/06/2011	03/07/2011				
		II	05/07/2011	19/07/2011	20/07/2011	28	45	2
Turtle 12	75.5	I	21/06/2011	08/07/2011				
		II	08/07/2011	24/07/2011				
		III	24/07/2011		05/08/2011[‡]	45	100	3
Turtle 13	75.0	I	21/06/2011		15/08/2011[‡]	55	91	2 - 3
Turtle 14	81.0	I	22/06/2011		10/07/2011	18	15	1
Turtle 15	91.0	I	25/06/2011		12/07/2011	17	25	1
Turtle 16	82.5	I	26/06/2011		29/07/2011	33	56	2
Turtle 17	87.0	I	30/06/2011		17/07/2011	17	25	1
Turtle 18	84.5	I	04/07/2011	19/07/2011		15	28	1
Turtle 19	78.0	I	07/07/2011		14/08/2011[‡]	38	58	2 - 3
Turtle 20	90.0	I	12/07/2011		14/08/2011	33	54	1
TOTAL						**666**	**1156**	**39**

Table 2.2. Summary data for the 4 loggerhead turtles that remained resident along Crete over the winter. One was tagged in 2010, left the site on August 11th 2010, but travelled to Gavdos Island south of Crete and remained there until the transmitter stopped emitting locations. I tracked the other three turtles during the egg-laying season and they remained around the island after the season was completed.

TURTLE ID	CCL (cm)	Departure from site	Last day of transmission	Days of observation	Total # of locations
Turtle A	82.0	11/08/2010	01/12/2010	112	87
Turtle 12	75.5	05/08/2011	21/01/2012	169	274
Turtle 13	75.0	15/08/2011	17/03/2012	215	119
Turtle 19	78.0	14/08/2011	25/01/2012	164	240
Total				660	720

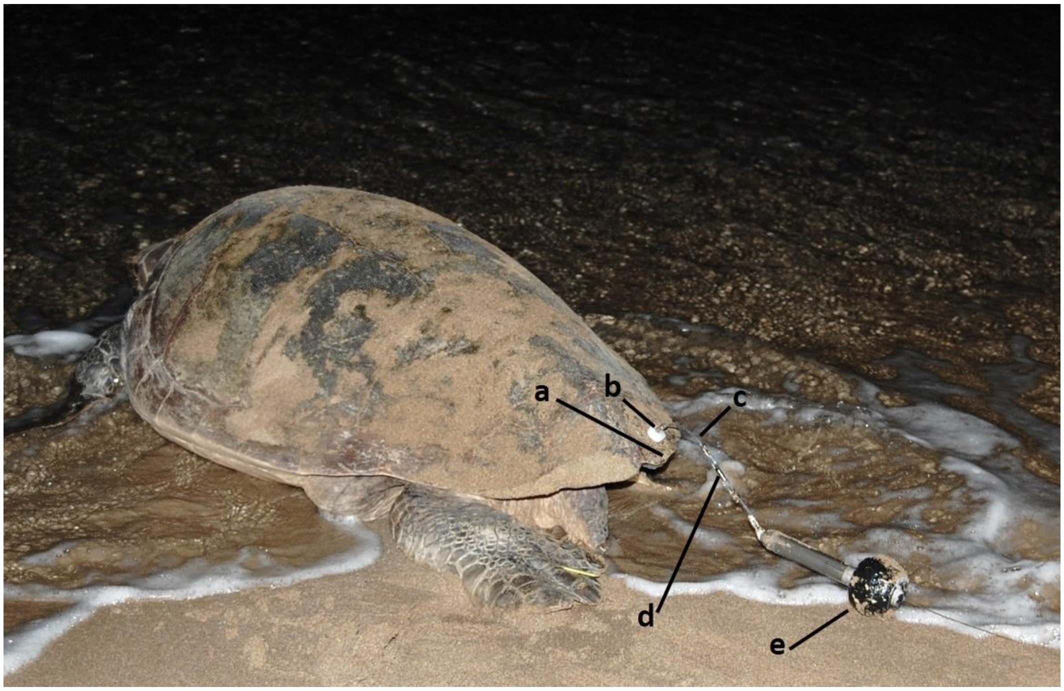

Figure 2.1. Satellite transmitter attachment on a loggerhead turtle at Rethymno, Crete. (a) supracaudal scute (b) upper plastic button (c) 172 kg test monofilament fishing line (d) corrosive link with metallic crimps and swivel and (e) satellite transmitter (Mk10 – Pop up Archival Tag).

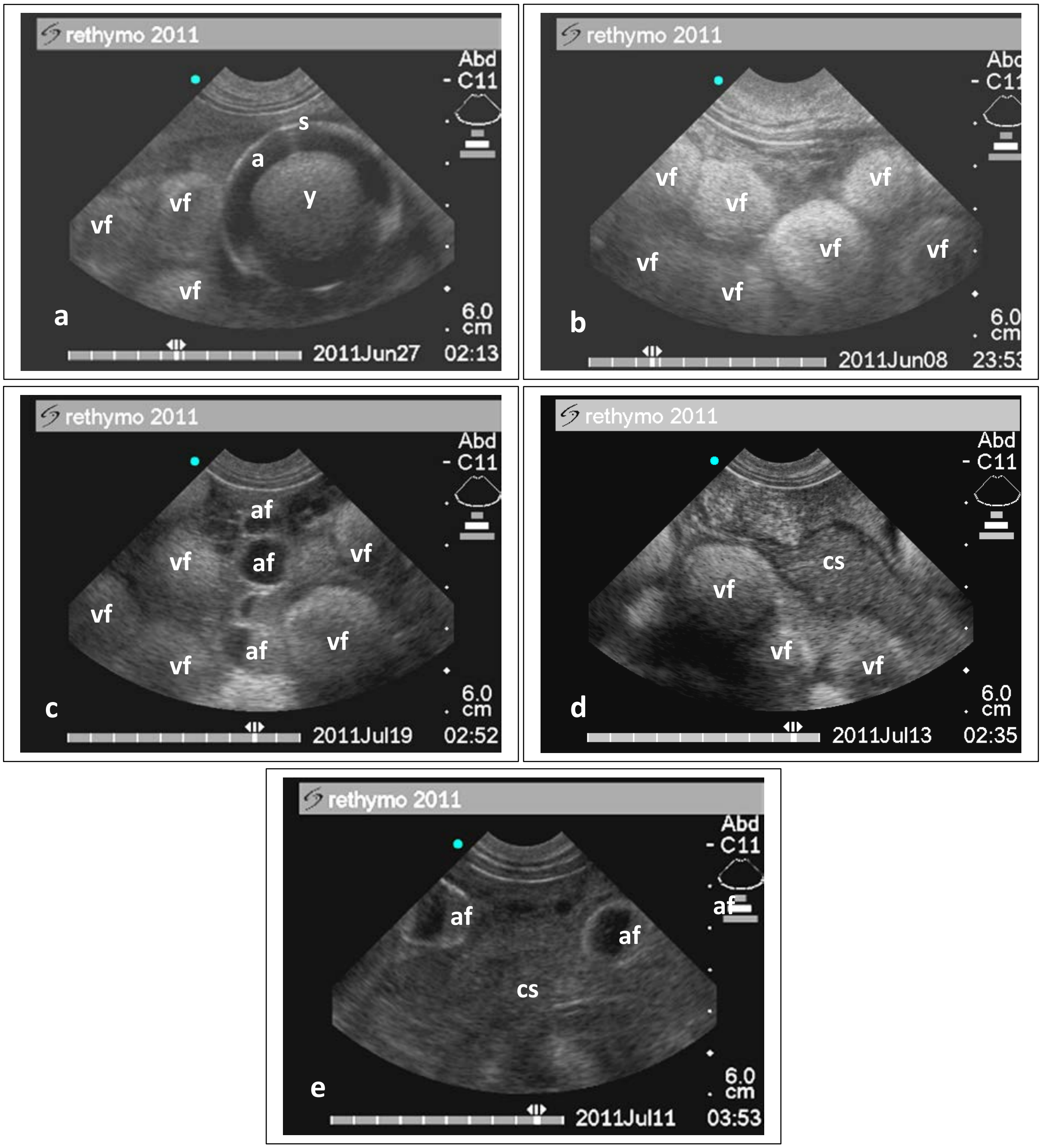
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Figure 2.2. Ultrasonographic images of ovaries of loggerhead turtles nesting in Rethymno. a) Early ovulatory. This turtle was examined before she had deposited her clutch so it is possible to observe both vitellogenic follicles (vf) and a fully shelled egg (s=shell, a=albumen, y=yolk). b) Early ovulatory. Only vitellogenic follicles with no coelomic space can be observed. c) Intermediate ovulatory. Vitellogenic follicles are present along with degenerating atretic follicles (af). d) Late ovulatory. Several vitellogenic follicles can be observed, however there is also coelomic space, suggesting that this turtle has only one more clutch left to deposit this season. e) Depleted ovary. Coelomic space, and atretic follicles with the characteristic “cat-eye” appearance can be observed.

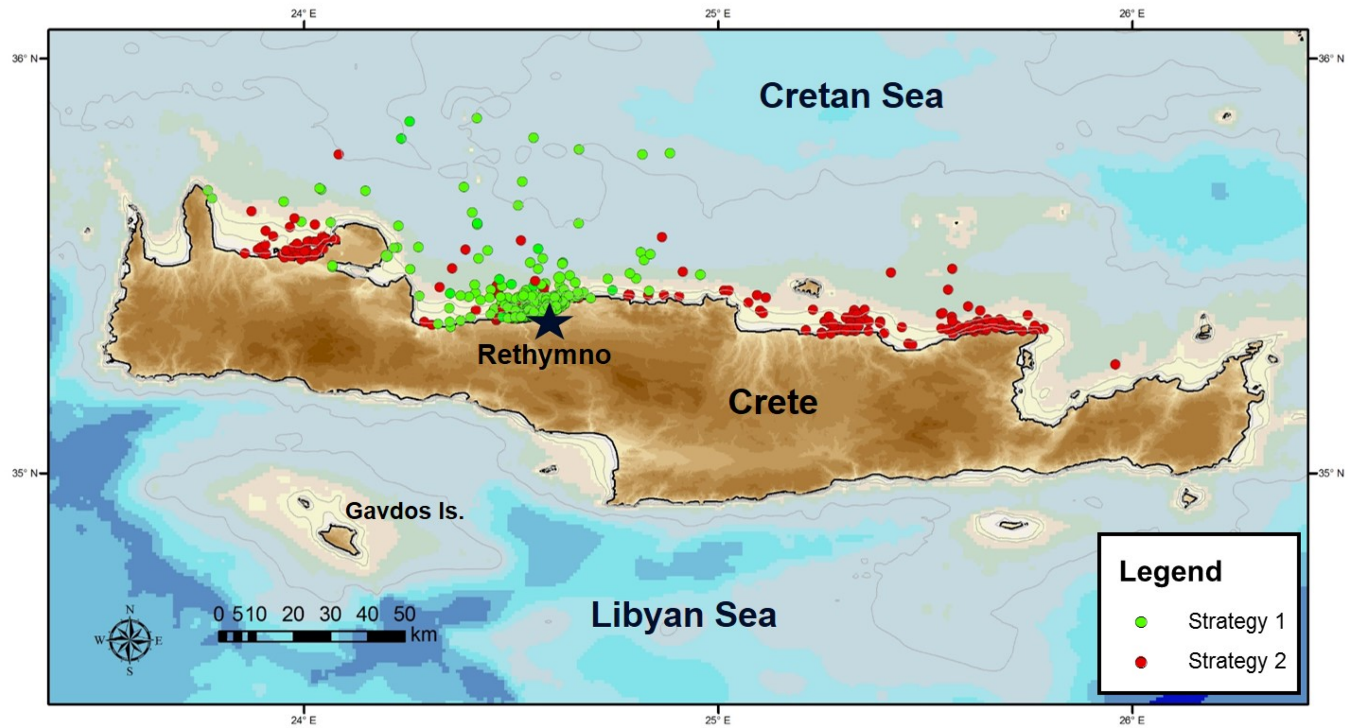

Figure 2.3. Locations of loggerhead turtles nesting at Rethymno, Crete, during the internesting interval. Each turtle had a floating satellite transmitter attached to the posterior edge of the carapace. The star indicates the original tagging site. Two nesting strategies existed. Most of the turtles (n = 15) remained close to the nesting beach, and returned after approximately 2 weeks for their subsequent clutch (Strategy 1, in green). Some turtles (n = 5) departed the beach and travelled as far as 150 km away where they probably deposited at least one clutch (Strategy 2, in red).

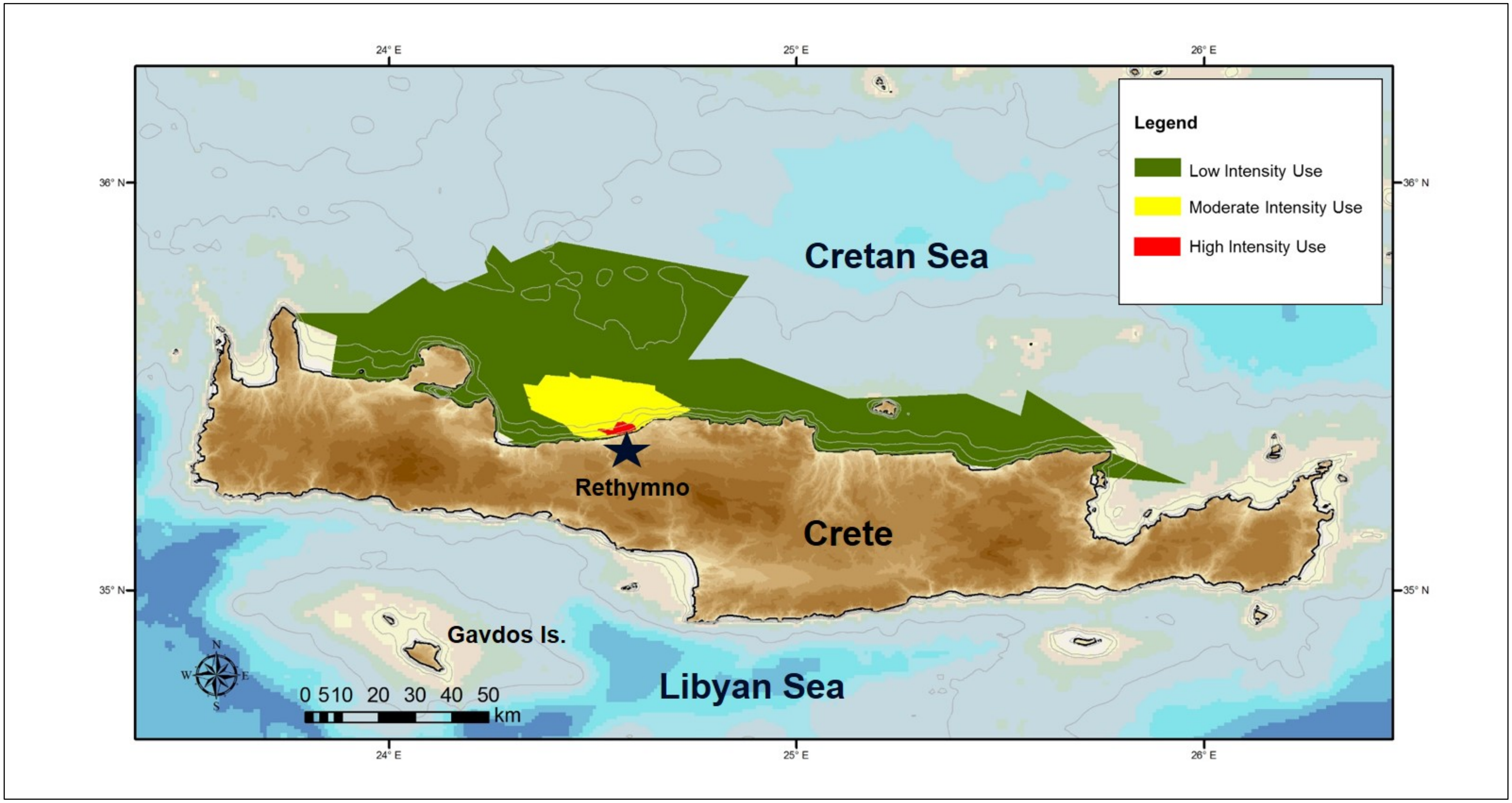

Figure 2.4. Internesting habitat of loggerhead turtles nesting at Rethymno. The High Intensity Use Area (in red color) was utilized by 15 – 19 turtles. Medium Intensity Use Area (in yellow) was untilized by 6 – 14 turtles. Low Intensity Use area was utilized by 1 – 5 turtles. The star indicates the location of the nesting site. The faint lines are depth isobaths for 10 m, 50 m and 100 m.

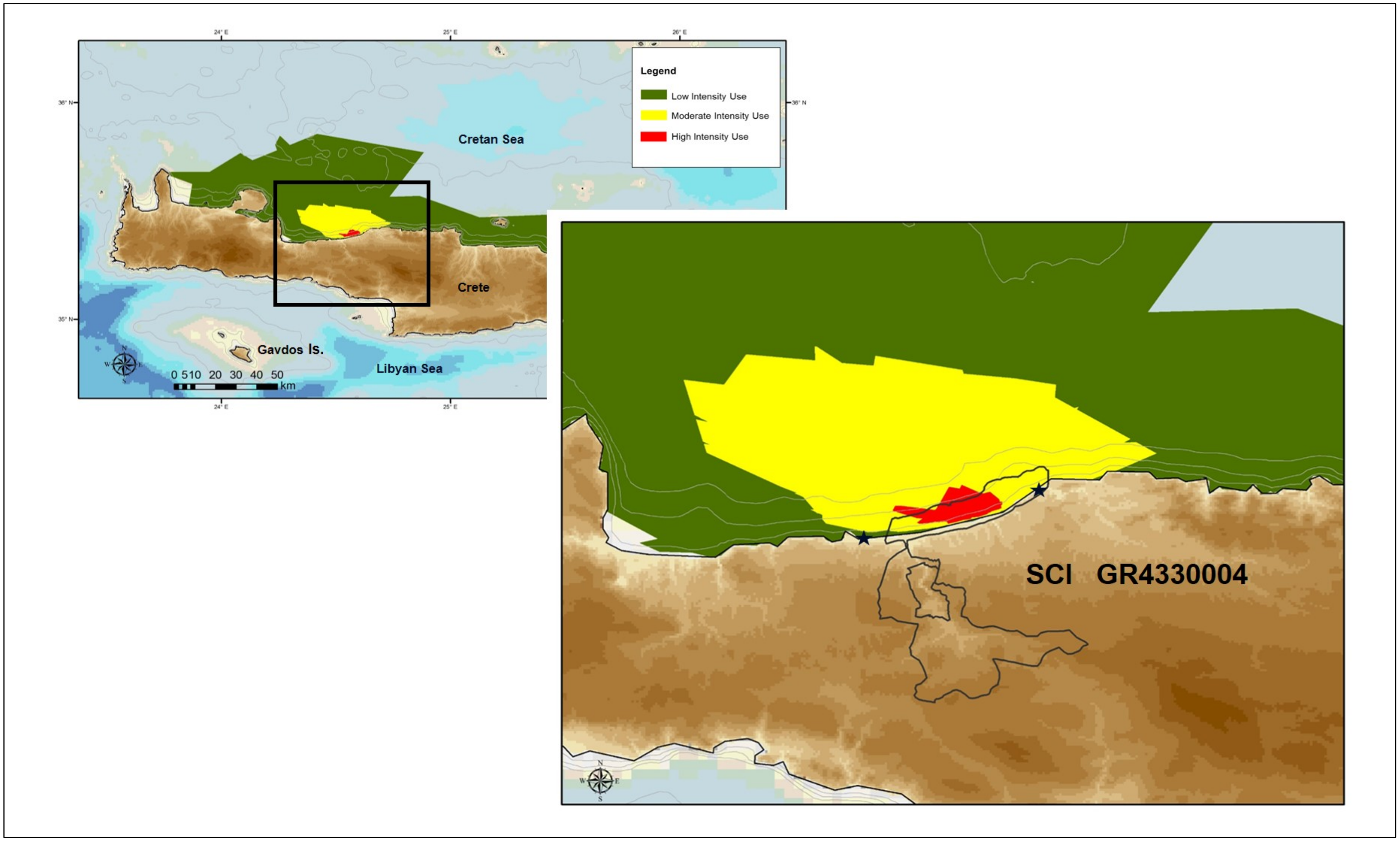

Figure 2.5. High and Moderate Use internesting habitat of loggerhead turtles nesting at Rethymno, Crete vs the NATURA 2000 protected area. Sea turtles utilize a larger area than what is included in the designated Site of Community Importance (SCI), here delineated in black line. Black stars indicate the boundaries of the monitored nesting site.

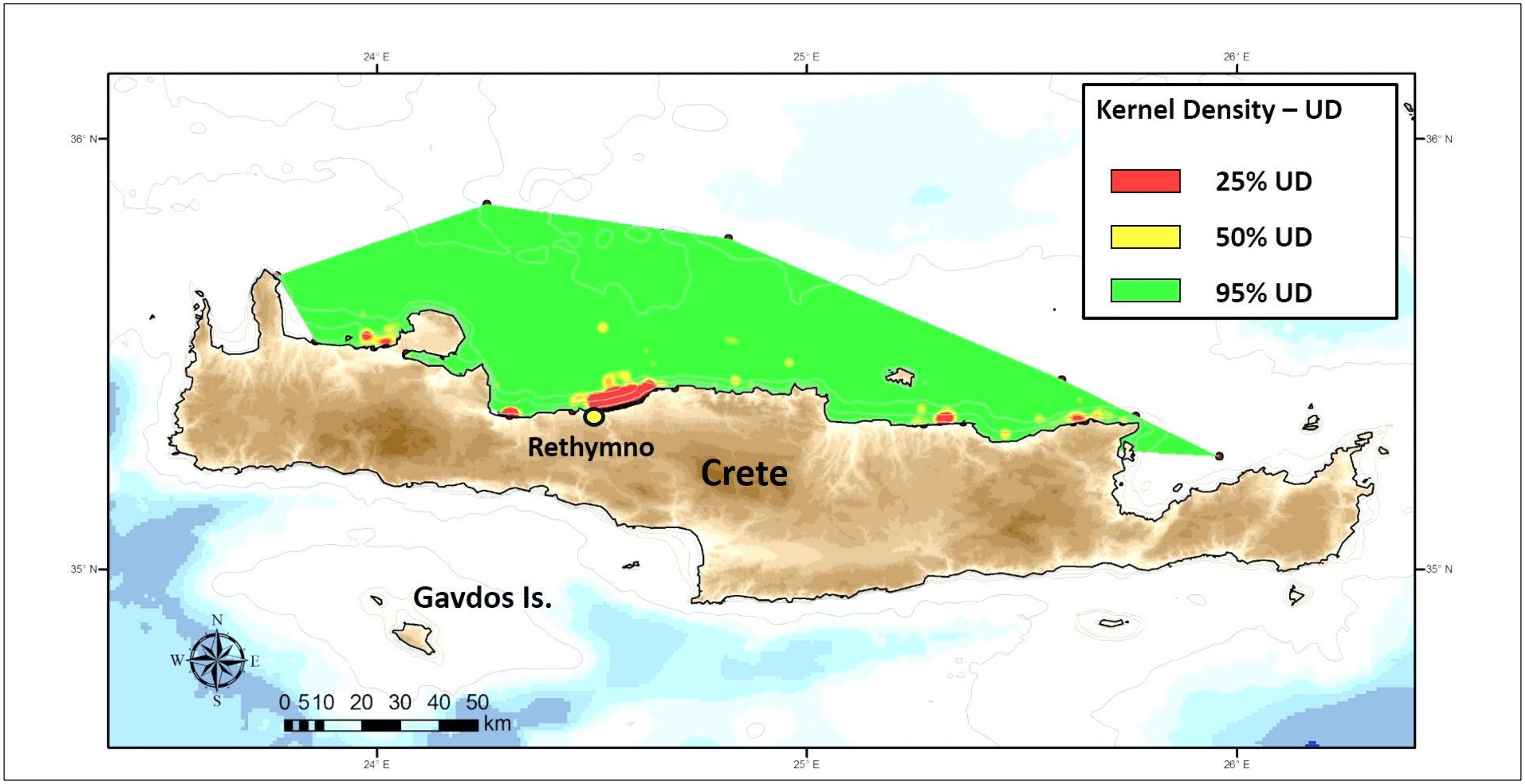

Figure 2.6. Kernel Density Analysis: Areas used by internesting loggerhead turtles from Rethymno. The green polygon indicates the 95% Utilization Distribution area, which extends from Cape Rodopou in the west to Mirabello Bay in the east. The 50% Utilization distribution area is indicated in yellow. The 25% UD core areas are indicated in red. (UD = Utilization Distribution).

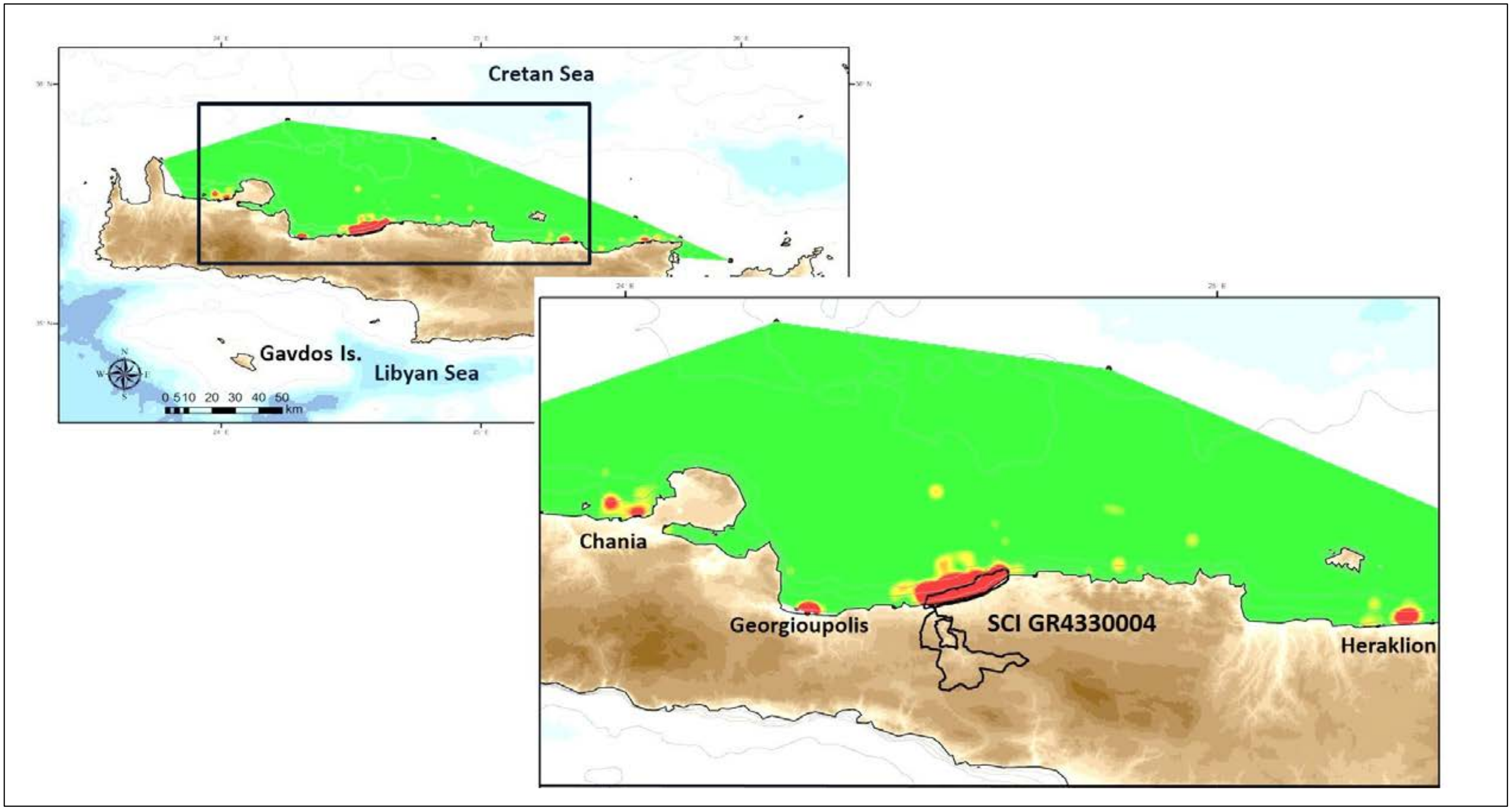

Figure 2.7. Kernel Density Analysis of internesting habitats for loggerhead turtles nesting in Rethymno vs the boundaries of the NATURA 2000 site. Large sections of the core areas utilized by sea turtles during the internesting interval lie well outside the designated Site of Community Importance (SCI), here delineated in black.

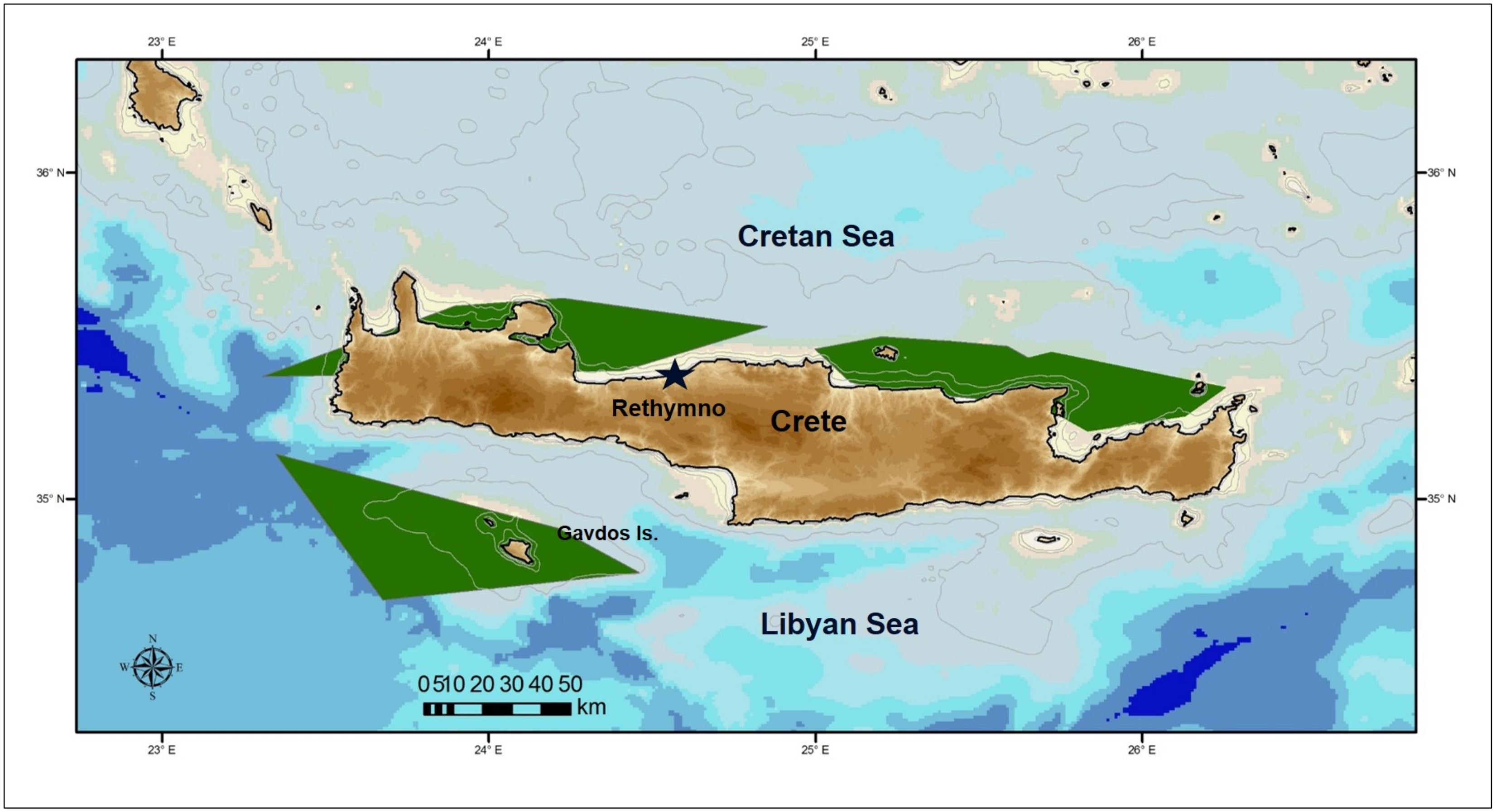

Figure 2.8. Overwintering areas for loggerhead turtles that remained resident along Crete. The star indicates the original nesting site. Data are from floating satellite transmitters attached to the rear of the turtle's carapace. One turtle tagged during the 2010 nesting season traveled to Gavdos, south of Crete, where she remained until the transmitter stopped emitting signals (1/12/2010). Three of the turtles tagged in 2011 remained resident in the area after depositing their last clutch. Minimum Convex Polygons for the turtles are indicated in green color.

Table 2.3. Table of loggerhead turtles selected from the database from which it was possible to derive clutch frequency information through direct observations (ECF_{OB}), ultrasonography (ECF_{US}) and satellite telemetry (ECF_{SAT}). OCF is the mean clutch frequency only for nests directly observed. ECF_{TOT} was estimated by combining the information derived from all three approaches. Females included in this dataset were all observed during the 2011 season.

Turtle ID	First seen	Last seen	Days	Departure from site / End of breeding season	Days	OCF	ECF_{OB}	ECF_{US}	ECF_{SAT}	ECF_{TOT}
Turtle A	01/06/2011	30/06/2011	30	24/07/2011	54	3	3	4	5	4
Turtle B	05/06/2011	05/06/2011	0	18/07/2011	43	1	1	2	4	4
Turtle C	06/06/2011	24/07/2011	49		(-)	3	4	4	4	4
Turtle D	07/06/2011	10/07/2011	33	30/07/2011	53	2	3	4	4	4
Turtle E	08/06/2011	25/07/2011	47	14/08/2011	66	4	4	5	5	6
Turtle F	13/06/2011	25/07/2011	42	27/07/2011	44	4	4	4	3	4
Turtle G	16/06/2011	03/07/2011	17		(-)	2	2	3	2	3
Turtle H	18/06/2011	18/07/2011	30		(-)	3	3	5	3	5
Turtle I	19/06/2011	19/07/2011	30	20/07/2011	1	3	3	4	3	4
Turtle J	21/06/2011	24/07/2011	33	05/08/2011	45	3	3	4	4	4
Turtle K	21/06/2011	21/06/2011	0	15/08/2011	55	1	1	2	5	2
Turtle L	22/06/2011	22/06/2011	0	10/07/2011	18	1	1	2	2	2
Turtle M	25/06/2011	25/06/2011	0	12/07/2011	17	1	1	3	2	3
Turtle N	26/06/2011	26/06/2011	0	29/07/2011	33	1	1	3	3	4
Turtle O	30/06/2011	30/06/2011	0	17/07/2011	18	1	1	3	2	3
Turtle P	07/07/2011	07/07/2011	0	14/08/2011	37	1	1	3	3	3
Turtle Q	10/07/2011	10/07/2011	0	10/07/2011	0	1	1	2	1	2
Turtle R	12/07/2011	26/07/2011	0	14/08/2011	19	2	1	3	2	3
Mean ± SD						2.1 ± 1.1	2.1 ± 1.2	3.3 ± 1.0	3.2 ± 1.2	3.6 ± 1.0
Mode						1	1	4	3	4

Chapter 3: Dive behavior during the internesting interval of loggerhead turtles *Caretta caretta* nesting in Rethymno, Greece.

Introduction

All seven species of sea turtle share very similar biological traits, especially when it comes to their reproduction (Ehrhart, 1982; Van Buskirk and Crowder, 1994; Musick and Limpus, 1997; Bowen and Karl 2007). In the months prior to nesting, vitellogenesis occurs in reproductively active females when previtellogenic follicles mature and increase in size within the ovaries (Rostal, et al., 1998; Hamann et al., 2003). Meanwhile, many reproductively active male and female turtles depart from their foraging sites and travel to their nesting beaches where they arrive several weeks before the breeding season begins (Miller, 1997; Plotkin, 2003). By the time courtship and mating occurs, the follicles are fully developed in the ovary (Rostal, 2007). Mating has been observed on the way to the nesting areas, at mating sites, or in close proximity to the nesting sites (Carr, et al. 1974; Pritchard, 1982; Eckert et al., 1989; Plotkin, 2003; James et al. 2005; Rostal, 2007; Morreale et al., 2007).

Sometime after mating, the first ovulation for the season occurs, a process during which the follicles are fertilized and mature into fully formed eggs (Owens, 1980; Hamann et al., 2003; Rostal, 2007; Rostal, 2015). Females proceed to lay their first clutch for the season. After the early part of the egg-laying season, testosterone levels drop in female turtles and they are no longer receptive to mating attempts (Rostal, et al., 1998), actively avoiding males attempting to copulate with them (Reina et al., 2005). With females no longer willing to mate, males depart the site to return to their foraging areas

(Miller, 1997; Hays et al., 2001; Plotkin, 2003; Schofield et al., 2010). Females remain in the area and proceed to lay several clutches of eggs over the nesting season at approximately two week intervals (Miller, 1997). Once the breeding season is complete, females return to their foraging/overwintering areas and it will be several years before they have replenished their energy reserves and will be ready to nest again (Miller, 1997; Hamman et al., 2003; Rostal, 2015).

Because a female can nest several times in a single season, the season is divided into two distinct processes: nesting and internesting. The period between two successive nesting events is defined as the internesting interval (Limpus, 1985; Houghton et al., 2002). For loggerhead turtles, *Caretta caretta*, clutch frequency is estimated at 1 - 7 nests per season (average: 3.5) with an internesting interval ranging from 9 – 21 days (summarized by Dodd, 1988; and by Schroeder et al., 2003; also see Panagopoulou, Chapter 2, this thesis). During the internesting intervals, sea turtles often spend a lot of their time in close proximity to the shore (reviewed in Panagopoulou, Chapter 2, this thesis). As a result, during this time they are particularly vulnerable to interactions with fisheries and other anthropogenic pressures (e.g. boat traffic, watersports). It is therefore important to identify and characterize the turtles' at-sea behavior during the internesting interval in order to assess and potentially mitigate such pressures.

This can be difficult to accomplish due to logistical and technological restrictions. However, the use of satellite telemetry and other electronic logging devices, particularly time-depth recorders (TDRs), has augmented our understanding, because the diving profiles they provide can be linked to specific at-sea behaviors (reviewed by (Hochscheid, 2014). For example, "U" shaped dives, defined by a steep descent to the maximum depth, a period spent at that depth and a steep ascent to the surface are often associated with resting (e.g. Minamikawa et al., 1997; Hays et al., 2000; Houghton et al., 2002; Reina et al., 2005; Blanco et al., 2013), benthic foraging (e.g. Hochscheid, 1999; Houghton et al., 2008) and horizontal movements (Seminoff et al., 2006). In contrast, shallow dive profiles of less than 2.5 m depth are suggestive of active swimming behavior (e.g. Reina et al., 2005; Houghton et al., 2008; Rice and Balazs, 2008) or foraging within the mid-water column (Seminoff et al., 2006). Many components of the diving behavior during the internesting interval are common across species and across populations, however some variation occurs. In general, diving behavior appears to be driven by energy optimization strategies, but it also may be shaped by local conditions and availability of food in the internesting habitat (Hays et al., 2000; Hays et al., 2002a; Houghton et al., 2002).

In areas where food resources are available, females can supplement energy needs during the nesting season by foraging, as has been observed in green turtles, *Chelonia mydas*, nesting in Cyprus (Hochscheid, 1999), along the Great Barrier Reef in Australia (Tucker and Read, 2001) and in leatherback turtles, *Dermochelys coriacea*, in French Guiana (Fossette et al., 2008) and the Caribbean (Byrne et al., 2009). In contrast, sea turtles may not forage at all during the internesting interval, using up energy reserves built up during the preceding foraging period as occurs in green turtles nesting in Ascension (Hays et al., 2002a), leatherback turtles (Reina et al., 2005; Perrault et al., 2014) and hawksbills, *Erethmochelys imbricata*, in Brazil (Santos et al., 2010). In Australia, loggerhead turtles use fat reserves accumulated before the start of the breeding season (Limpus and Limpus, 2003). However, Schofield et al. (2007) observed instances of opportunistic benthic feeding in loggerheads nesting on Zakynthos, Greece, so it is possible that this species may forage during the internesting interval if food is available.

Internesting behavior is also influenced by environmental conditions: eastern Pacific leatherback turtle behavioral patterns shift depending on the ambient ocean conditions such as temperature (Shillinger et al., 2010). Similarly, loggerheads nesting in Greece appear to be thermally selecting habitats to optimize maturation of the eggs, especially at the start of the nesting season (Schofield et al., 2009; Fossette et al., 2012; Backof, 2013).

The observed variation in behavior becomes important when defining management measures for specific populations. Rethymno on Crete hosts the third largest nesting aggregation of loggerheads in Greece, accounting for approximately 9% of the total nesting effort recorded in the Mediterranean (Margaritoulis et al., 2003; Margaritoulis 2005; Margaritoulis and Panagopoulou, 2010). Its regional importance for Mediterranean turtles was a major contributing factor to the inclusion of 80% of the site in European Union’s NATURA 2000 Network. Under European law, Greece will have to design and implement management measures for the site, including the marine area adjacent to the nesting beach that extends up to the 50 m isobath. The main objective of my study was to quantify the behavior exhibited by loggerhead turtles nesting in Rethymno during the internesting interval because such information is key for the conservation and management of this population. To achieve this, I recorded different diving parameters such as maximum dive depth, dive duration, time at depth and number of dives per four-hour period to characterize the turtles’ vertical usage of the water column. I hypothesized that turtle behavior would be similar to that exhibited by other loggerhead populations in the Mediterranean and that diving patterns would be driven by energy conservation strategies. I expected the Rethymno loggerheads to spend long periods of time largely inactive, resting at the sea bottom or at the surface. This was a novel approach to study diving behavior of sea turtles and it identified key elements in behavior within the high-use habitat near Rethymno (Panagopoulou, Chapter 2, this thesis).

Materials and Methods

To collect data on the diving behavior during the internesting interval, I used direct observations, ultrasonography and a combination of Temperature-Depth data loggers (2010 – 2012) and satellite transmitters (2011) deployed on 33 female loggerheads nesting in Rethymno, Crete. The study took place during the 2010, 2011 and 2012 nesting seasons and was conducted in collaboration with ARCHELON, the Sea Turtle Protection Society of Greece.

Between the months of June and August of each season, my research team and I patrolled the easternmost 2.5 km of the Rethymno site at night in search of nesting loggerhead turtles. I selected this section of the beach because it was known to exhibit the highest nest density for the Rethymno site (ARCHELON, unpublished data). When I encountered a nesting female, I waited until she finished laying her eggs and started covering the egg-chamber. At that point, I measured the curved and straight carapace length (CCL, SCL) and curved and straight carapace width (CCW, SCW). Next, I applied two external flipper tags for the ARCHELON monitoring project. These tags identified individual turtles included in my study. While the turtle continued covering her egg chamber, I performed an ultrasound examination to assess if she had enlarged follicles in her ovary. The presence of such follicles suggested that the female would probably return in approximately two weeks to lay another clutch and, therefore, was suitable for my study. I then attached a satellite transmitter, a data logger, or both to the carapace. When I re-encountered the turtle during a subsequent nesting event, I performed another ultrasound, retrieved the attached data logger and/or transmitter, and if I observed more enlarged follicles in her ovary continued to study her by deploying new equipment.

Ultrasound examination

To assess the turtle's reproductive status, I used real-time portable ultrasound scanners following the method developed by Rostal et al., (1990) and adapted by Blanco et al., (2012). In 2010, I used an Aloka-SSD500 scanner (Hitachi ALOKA Medical, Co. Ltd, Tokyo, Japan), plugged into a portable battery. I performed ultrasound scans using a 3.5 MHz transducer (maximum display depth: 22 cm) and recorded results via a portable printer attached to the scanner. During 2011 and 2012 I used a Sonosite 180 Vet Plus (Sonosite, Inc, Bothell, Washington) with a C60/5-2 MHz transducer (display depth: 6 cm), digitally storing the ultrasound images for later transfer to a laptop computer. Prior to examination I coated the probe with acoustic coupling gel (Aquasonic® 100, Parker Laboratories Inc., New Jersey) to maintain contact and enhance the quality of the imaging. I visualized each ovary and oviduct by placing the transducer on the soft-tissue in the inguinal area lateral to the plastron and cranial to the femurs of both the right and left sides of the turtle and orienting the probe towards the contralateral flipper. This acoustic window provided the optimal position for imaging of the turtle's reproductive structures (Valente et al., 2007). This non-invasive process took approximately 5 minutes for each scanned turtle and the turtles appeared completely unaffected throughout it.

Satellite transmitters and data loggers

To obtain fine-scale data on diving behavior, I used Lotek LAT1100 Time Temperature and Depth data loggers (Lotek Wireless Inc., Ontario, Canada) on 32 turtles (2010 = 8, 2011 = 8, 2012 = 16). During 2011, I also collected diving behavior data by deploying Mk10-PAT and Mk10-AF with Fastloc® capabilities (Wildlife Computers, Redmond, Washington) on 20 females, four of which also carried data loggers. All turtles were reproductively active loggerheads likely to return within approximately two weeks to lay another clutch.

Attachment method

For the deployment of data loggers and the satellite transmitters, I followed a procedure created by Standora et al. (1982), further developed by Morreale et al. (1996), Morreale (1999) and modified by Blanco et al. (2013). This technique entailed attaching the transmitter on a tether that trailed the turtle as she was swimming. I further adapted the deployment method for the data loggers, which were directly attached on the carapace (Figure 3.1). First, I cleaned the area on one of the two supracaudal scutes using 70% alcohol to remove all traces of sand and to disinfect the area where the data logger or transmitter would be attached. Then I made a small circular incision (5 mm) at a distance less than 2 cm from the outer edge of the supracaudal scute. I immediately disinfected the incision using a Povidone-iodine based topical antiseptic solution. Next, I assembled the tether that would be used for securing the equipment on the carapace. I used monofilament fishing line for both types of attachment (data loggers: 45 kg test; satellite transmitters: 180 kg test). I selected a lighter test line for the data loggers because it was attached directly on the carapace. I subsequently inserted sterilized surgical tubing (3.2 mm inside diameter, 6.4 mm outside diameter and 1.6 mm wall thickness) through the incision. The surgical tubing prevented direct contact between the tether and the carapace, protecting it from abrasion. Then I inserted the monofilament fishing line through the rubber tubing, through a custom-made button on the ventral side of the carapace and back through the tubing. The fishing line also passed through another button on the dorsal side of the carapace. The relatively soft buttons were made of high-density polyethylene with smooth edges, and prevented contact between the tether and the carapace and spread the force of the transmitter, limiting the impact of the attachment. To attach the data logger, I passed the monofilament line through the two holes on either side of the data logger, securing it onto a small custom-made button, and finally through a double-barreled 1.6 mm diameter crimp. To deploy the satellite transmitter, I used two double-barreled 2.2 mm diameter crimps to secure the tether onto the carapace and onto the device. In approximately the middle of the tether, I added a 172 kg test swivel to allow for rotational movement of the satellite transmitter as it trailed behind the turtle. The crimps and swivels used were made of corrodible materials intended to break away within a year or less. The total length of the transmitter tether ranged from 15 – 25 cm, and was adjusted to ensure that it would not become entangled or interfere with the movement of the front or rear flippers of the animal. Some females were fitted with both a satellite transmitter and a data logger at the same time. In that case, I first attached the satellite transmitter and then attached the data logger, by following the same procedure, and making a second incision on the marginal scute adjacent to that where the transmitter was attached.

The entire process lasted between 7 and 10 minutes if only one of the two instruments was applied, and 15 – 17 minutes when both a data logger and a satellite transmitter were deployed on the same individual. This attachment method greatly reduced the need to restrain the turtle and minimized the stress on the turtle while on land. Further advantages of this attachment method include lower level of drag as compared to non-hydrodynamic objects directly attached onto the anterior areas of the carapace (Logan and Morreale, 1994; Watson and Granger, 1988; Jones et al., 2013).

Time-Depth Data Loggers

The Time-Depth data loggers used in this study measured 31.5 mm by 15 mm by 5.6 mm and weighed approximately 30 g. They included sensors for pressure (in dBar) and temperature (in °C). In 2010 and 2011, I programmed the data loggers to record pressure every 24 sec because that sampling interval allowed for a detailed diving profile over a maximum of 24 days (total of 86,400 samplings), without exceeding the memory limit of the device (128 k). This was approximately 25% above the longest mean internesting interval of 19 days recorded for loggerhead turtles (Dodd, 1988; Margaritoulis et al., 2003). In 2012, I reduced the sampling interval to every 80 sec so as to be able to collect data over a longer period of time that might encompass more than one internesting intervals (42 days, 45,360 samplings).

When I retrieved a data logger, I downloaded the data in binary files using LOTEK's TagTalk program. I subsequently imported the data onto a text file for further organization and analyses using both Excel and dBase Plus™ software. I converted pressure readings to depth using the Saunders and Fofonoff equation (1976), which is included in UNESCO's handbook "Algorithms for Computation of Fundamental Properties of Sea Water" (Marine Science, No 44). This formula can convert pressure to depth in most regions of the world, with an accuracy of 0.25 m (Saunders and Fofonoff, 1976). The formula takes water density into account and an ocean water column at 30° latitude, 0 °C, and 35 ‰ salinity are assumed.

First, I calculated gravity variation using the equation:

$$g\ (m/sec^2) = 9.780318 * [\ 1.0 + (\ 5.2788x10^{-3} + 2.36x10^{-5} * x) * x\ ] + 1.092x10^{-6} * p$$

Where:

$x = [\sin(\text{latitude} / 57.29578)]^2$

p = pressure (dBar), as measured by the data logger

Then, I calculated depth from pressure as:

$$\text{Depth (m)} = [(((-1.82x10^{-15} * p + 2.279x10^{-10}) * p - 2.2512x10^{-5}) * p + 9.72659) * p] / g$$

Where:

p = pressure (dBar), as measured by the data logger

g = gravity (m/sec^2)

After converting pressure to depth, I classified depth values as "S" for surface, or "D" for dive. I assigned a value of "S"/surface to any depth shallower than 1 m because the nominal accuracy of the data logger was (± 0.4 m), and the device was attached to the posterior section of the carapace which can be submerged even as the female is at the surface breathing. A submergence event (referred to as "dive" from this point forward) was defined as the period between two "S" values. For each dive, I calculated the maximum depth and dive duration, and categorized it into one of six four-hour periods of the day in UTC time so that those data would be comparable with those derived from the satellite transmitters, taken in 4 hour increments starting at 00:00 h (In UTC + 3: Period 1 = 03:00 – 06:59; Period 2 = 07:00 – 10:59; Period 3 = 11:00 – 14:59; Period 4 = 15:00 – 18:59; Period 5 = 19:00 – 22:59; Period 6 = 23:00 – 02:59). Conversion to depth, classification of dives and basic dive data were calculated scripts and algorithms using dBase Plus™ software (© dataBased Intelligence Inc, 1999-2008).

Satellite Transmitters

To increase buoyancy, I modified the Mk10-PAT transmitters to ensure a device would be in an upright position as the turtle came to the surface, thus improving transmission of data to the Argos System (Blanco et al., 2012; Patel, 2013). I encased the smaller transmitter float in a hydrodynamically shaped cone made of syntactic foam taking care to keep the sensor and antenna areas free. The modified transmitters weighed approximately 115 g, and had a buoyancy of about 36 g (Blanco et al., 2013; Patel, 2013). The transmitter's hydrodynamic shape and the resulting buoyancy, combined with its position in relation to the body of the turtle, allowed for the transmitter to remain in the turtle's slip stream as it swam greatly reducing drag (Logan and Morreale 2003).

I set the transmitters onto a 24 h on duty cycle, limiting the number of transmissions to 52 per day, and having unused transmissions carried over to the next day. Transmitters sampled, recorded and transmitted data on dive depth (accuracy to within 0.5 m), dive duration (in seconds), time at depth (in percentages) and temperature (in °C) as histograms summarizing 4-hour periods set in UTC time as well as time series with a sampling interval of 10 min. I converted these periods to Greek time zone (UTC + 3 h), which was the one the animal was experiencing at the time it was under study (In UTC + 3: Period 1 = 03:00 – 06:59; Period 2 = 07:00 – 10:59; Period 3 = 11:00 – 14:59; Period 4 = 15:00 – 18:59; Period 5 = 19:00 – 22:59; Period 6 = 23:00 – 02:59). A dive was defined as a submergence event reaching a depth of below 1 m and lasting more than 1 min. I pre-determined bins for dive depth at 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 75, 100, 200 and > 200 m. The 5 m bin included dive measurements ranging from -1.5 m to -5.0 m, the 10 m bin included values ranging from 5.5 m to 10.0 meters… etc. The final bin encompassed values deeper than -200.5 m. Dive duration bins were predetermined at 2.0 min (61 – 120 sec), 5.0 min (121 – 300 sec), 10.0 min (301 – 600 sec), 20.0 min (601 – 1,200 sec), 30.0 min (1,201 – 1,800 sec), 40.0 min (1,801 – 2,400 sec), 50.0 min (2,401 – 3,000 sec) , 60.0 min (3,001 – 3,600 sec), 90.0 min (3601 – 5,400 sec), and > 90 min (> 5,400 sec). When I retrieved the transmitter, I downloaded the data collected before resetting the transmitter for future attachment. In the cases where the transmitter was not retrieved, I used the Argos system to download partial data until the end of the breeding season for that turtle, which was signified by the departure of the animal from the nesting site (Miller, 1997; Plotkin and Spotila, 2002; Miller et al., 2003; Schroeder et al., 2003). For the turtles that later remained resident on the island and were assessed to still be internesting (Panagopoulou, Chapter 2, this thesis), I continued to monitor them until the 14th of August, when > 95% of all nesting activity is complete for loggerheads nesting in the Mediterranean (Margaritoulis and Rees, 2001; Margaritoulis et al., 2003; Margaritoulis, 2005).

Statistical analyses

I conducted all statistical analyses using R (R Core Team, 2014). To provide a general outline of dive behavior derived from data loggers, I estimated the mean, median, standard deviation and maximum values for depth and dive duration for all dives. For data loggers, I excluded all dives shallower than 2 m deep, classifying them as surface activity, because the resolution and the sampling interval made it difficult to differentiate between breathing events and diving behavioral patterns at very shallow depths (Hochscheid, 1999; Cheng, 2009). I used the term “biological dive” in reference to the remaining dives (deeper than 2 m) used for statistical analyses. I explored the relationship between dive depth and dive duration by conducting Kendall’s tau correlation test for non-parametric variables.

Satellite transmitters had a 10 min sampling interval. Therefore, I did not obtain detailed dive profiles from the satellite-tracked turtles, and as such, was not able to identify individual dives. However, I summarized the data derived from satellite transmitters and data loggers into frequency tables for dive depth (bins: 5 m, 10 m, more than 10 m) and dive duration (bins: 5 min, 10 min, 20 min, more than 20 min). I performed chi square goodness of fit tests (x^2) for dive depth and dive duration, to determine the relationship between individual turtles' behavior and the average values for the total number of turtles studied. To ensure that the measures were independent and not auto correlated for this analysis, I included only the first internesting interval recorded from each of the satellite tracked turtles. Expected values were derived from the total number of dives used in the chi square analysis. Finally, I explored the standardized residuals derived from the chi square tests to identify which turtles' diving behavior significantly differed from the expected values.

To examine possible variation in behavior during different times of day, I selected behavioral parameters and grouped them into six four-hour periods. For data loggers, I selected dive duration and number of dives as indicators of activity and I conducted one-way analyses of variance (ANOVA; statistical significance at a level of 0.05), with Tukey's post-hoc pairwise comparison tests (statistical significance at a level of 0.05), to investigate pairwise mean differences among periods for the two parameters. For satellite transmitter data, I selected number of dives and time at depth as proxies, and I conducted One-way Analyses of Variance (ANOVA; statistical significance at a level of 0.05), with Tukey's post-hoc test (statistical significance at a level of 0.05), to explore pairwise mean differences among the six periods for both parameters.

The study was approved by the Animal Care and Use Committee of Drexel University and conducted under ARCHELON's research permit provided by the Ministry of Agriculture of Greece.

Results

During the sea turtle nesting seasons of 2010, 2011 and 2012, I deployed Time-Depth data loggers on 32 turtles (2010 = 8; 2011 = 8; 2012 = 16). I retrieved 20 of these loggers (2010 = 3; 2011 = 5; 2012 = 12) as the turtles were encountered later. One logger had a problem with the settings program and therefore the data recorded were not comparable with the others; the data produced by a second logger indicated that the female was underwater for exceptionally long periods of time (> 8 h), which is unlikely to have occurred. I excluded both of these loggers from analyses. The remaining 18 data loggers (RET 1- RET 18) represented one internesting interval per turtle, with the exception of RET 12 and RET 15, that were retrieved after the course of two and three intervals respectively (Table 3.1).

In 2011, I deployed satellite transmitters on 20 females assessed to be internesting as a result of ultrasound examination (Turtles 01-20). Nine of these females were monitored for more than one internesting interval, as the transmitters were replaced when these turtles were re-encountered (Table 3.2). One transmitter (Turtle 06) stopped transmitting as the female was returning for her second nest. She was re-encountered on 27/07/2011, with signs of the device having physically been removed by a third party. A second transmitter, (Turtle 09), stopped transmitting information half-way through the internesting interval, but the female was not encountered again. I attributed malfunction of the device as the most likely cause for the stoppage.

Overall, the satellite transmitters recorded complete data from 17 internesting intervals and emitted truncated data from an additional 20; I downloaded those data via the ARGOS satellite system. Four females were fitted simultaneously with a data logger and a satellite transmitter. One female had a remigration interval of one year and was observed both in 2010 (data logger) and 2011 (satellite transmitter). Therefore, a total of 33 turtles were included in this study.

Diving behavior – data loggers

From the 18 retrieved data loggers, I identified 8,241 individual dives. Females mostly occupied shallow depths, with 58.5% of all dives occurring at depths between 2 and 5 m. Only 10.8% of the dives were deeper than 10 m (Figure 3.2 a, b; Figure 3.3). The average dive depth was 5.8 ± 5.9 m, median 4.4 m. Only a small proportion of the dives occurred to depths deeper than 30 m (n = 43) and only 8 out of 18 monitored individuals exhibited such dives. The deepest dives (Figure 3.4) were at 60.2 m (RET 02), 69.0 m (RET 05), 60.4 m (RET 07), 64.2 m (RET 12) and 68.3 m (RET 15).

Similarly, turtles did not spend long periods of time underwater when diving (Figure 3.5). Average dive duration was 10.9 ± 11.4 min, with a median value of 6.4 min. Nearly half, 44.2%, of all dives lasted 5 min or less, and only 20.2% lasted more than 20 min (Figure 3.2). Five females made dives longer than 60 min: RET 12 (longest dive: 96 minutes), RET 13 (longest dive: 82.7 min), RET 15 (longest dive: 98.7 min), RET 16 (longest dive: 61.3 min) and RET 17 (126.7 min) (Figure 3.5).

Kendall's tau correlation test for non-parametric variables revealed that there was a weak relationship between dive depth and dive duration (tau coefficient $\tau = -0.29$, $p < 0.001$). Many shallow dives (< 5 m) lasted longer than 20 min (n = 504). Similarly, many dives lasting a shorter period of time (< 5 min) occurred at depths deeper than 10 m (n = 236) (Figure 3.6).

A chi square goodness of fit test for dive depth and dive duration for data loggers indicated that there was significant deviation from the average values for depth (x^2 = 585.5, degrees of freedom = 34, $p < 0.001$) and duration of dives (x^2 = 1,558, degrees of freedom = 51, $p < 0.001$). I assessed the degree to which females deviated from the average values (Figure 3.2 a and b), by exploring the standardized residuals derived from the chi square test. Some turtles performed more dives at shallow depths than the average recorded (e.g. RET 02, RET 15) and others conducted more dives at depths deeper than 10 m than the average recorded (e.g. RET 05, RET 12, RET 17). Some females (RET 02, RET 04, RET 05, RET 15) engaged in significantly more dives of 5 min or less, and fewer dives lasting longer than 20 min. In contrast, other turtles (RET 06, RET 08, RET 13, RET 17, RET 18) engaged in significantly fewer dives of 5 min or less and more dives lasting longer than 20 min. By combining these data, I was able to describe variability in behavior during the internesting interval for individual turtles. For example, RET 15 engaged in more dives at very shallow depths (< 5 m) than average, but also engaged in significantly more 10 and 20 minute dives than expected, which was indicative of large periods of inactivity (Figure 3.7a). RET 02 underwent substantially more dives at shallow depths, but also exhibited a more active behavioral pattern by having a higher than average proportion of dives lasting less than 5 min (Figure 3.7b). RET 13 exhibited a less active behavior by engaging in fewer than average dives of less than 5 min and more dives lasting longer than 20 min (Figure 3.7b).

Analysis of Variance (ANOVA) test revealed significant differences in dive duration over the course of the day ($F_{5, 8239}$ = 180.6, $p < 0.001$) and number of dives ($F_{5, 1282}$ = 5.865, $p < 0.001$) (Figures 3.8 and 3.9). Mean dive duration was longer between 03:00 and 14:59 h than between 15:00 and 02:59 h (Period 1: $t_{4,1}$ = -9.118, $t_{5,1}$ = -11.353, $t_{6,1}$ = -7.719, p <0.001; period 2: $t_{4,2}$ = -9.533, $t_{5,2}$ = -11.677, $t_{6,2}$ = -8.199, p < 0.001; Period 3: $t_{4,3}$ = -7.964, $t_{5,3}$ = -9.698, $t_{6,3}$ = -6.581, p <0.001). Tukey's pairwise comparison test showed that the mean number of dives was significantly lower during period 3 (11:00 – 14:59) as compared to periods 1 (03:00 – 06:59), 5 (19:00 – 22:59) and 6 (23:00 – 03:59) ($t_{3,1}$ = -4.502, p < 0.001; $t_{3,2}$ = -3.790, p = 0.002; $t_{4,3}$ = 1.48, p = 0.677; $t_{5,3}$ = 3.565, p = 0.005; $t_{6,3}$ = 3.919, p = 0.001). Period 4 did not show any statistically significant differences with Period 3 (15:00 – 18:59) ($t_{4,3}$ = 1.480, p = 0.677).

Diving behavior – satellite transmitters

From the 20 satellite tracked turtles, I retrieved complete data from 17 internesting intervals and truncated data from an additional 20. In total, I collected 4-h summarized information (histograms) for dive depth (n = 1,998; 30,804 dives), dive duration (n = 2,002; 30,870 dives) and time at depth (n = 2,159). Females occupied mostly shallow depths when diving, with 86.9% of the dives having a maximum depth of 5 m and 3.2 % occurring at depths deeper than 10 m (Figure 3.2c; Figure 3.2d). Very few dives were deeper than 30 m (n = 98), and 45 went deeper than 75 m. Those deepest dives were from 9 out of 20 individuals (Turtle 01, Turtle 06, Turtle 07, Turtle 08, Turtle 11, Turtle 12, Turtle, 13, Turtle 18 and Turtle 19). Dive duration varied among the designated bins, with 32.6%, 19.1%, 28.7% and 19.4% of the dives lasting 5 min, 10 min, 20 min and more than 20 min respectively. I recorded 2,578 dives lasting longer than 30 min (8.3%), and those dives were exhibited by nearly all individuals (Figure 3.10b); Figure 3.2d).

To examine variability in behavior among individual females, I performed a chi square goodness of fit test for dive depth and dive duration. In order for the data to be consistent with those of data loggers I included only the first internesting interval. As in the case of the data loggers, there were statistically significant differences in behavior among individual turtles, both in terms of dive depth ($x^2 = 2{,}668.8$, degrees of freedom = 38, $p < 0.001$) and dive duration ($x^2 = 1{,}516.4$, degrees of freedom = 57, $p < 0.001$). I explored the standardized residuals derived from the chi square tests to assess which females deviated the most from the average values (Figure 3.2 c and d). Similar to data from the data loggers, some females dove for 5 min or less more frequently than expected and had significantly fewer dives of 20 min or more (Turtle 05, Turtle 08, Turtle 12, Turtle 20). In contrast, other turtles (Turtle 01, Turtle 02, Turtle 03, Turtle 11, Turtle 15 and Turtle 19) had significantly more dives of longer duration. As in the case of data loggers, by combining these data I was able to describe variability in behavior during the internesting interval for individual turtles. For example, Turtle 08 underwent significantly more than average dives at depths less than 5 m and more dives less than 5 min long, indicating an active behavioral pattern occurring at shallow depths (Figure 3.11a). In contrast, Turtle 18 maintained a low level of diving activity by conducting more dives deeper than 10 m more frequently and exhibiting significantly more than the average dives lasting more than 20 min (Figure 3.11b. Of particular interest was Turtle 19, which exhibited the highest variation from average values both in terms of dive depth and dive duration. That female had maturing follicles in her ovaries at the time she was first encountered, and then she migrated to the east of Crete where I assume she deposited at least one more clutch (Panagopoulou, Chapter 2, this thesis) (Figure 3.11c).

Analysis of Variance (ANOVA) test yielded significant differences in number of dives over the course of the day ($F_{5, 1268} = 12.5$, $p < 0.001$) and percentage of time at depth ($F_{5,2085} = 18.77$, $p < 0.001$) (Figures 3.12 and 3.13). Females spent more time submerged at depths deeper than 5 m during Periods 1 and 2 (03:00 – 10:59) as compared to the rest of the day, especially periods 3 and 4 (11:00 – 18:59) ($t_{2,1} = 3.023$, $p = 0.03$; $t_{3,1} = 6.837$, $p < 0.001$; $t_{4,1} = 7.965$, $p < 0.001$; $t_{5,1} = 7.389$, $p < 0.001$; $t_{6,1} = 4.597$, $p < 0.001$; $t_{3,2} = 3.808$, $p = 0.002$; $t_{4,2} = 4.944$, $p < 0.001$; $t_{5,2} = 4.353$).

Finally, I calculated average temperatures experienced by sea turtles during a 24 hour period, which ranged from 24.4 to 25.6°C (Figure 3.14).

Discussion

In this study, I used data loggers and satellite transmitters to explore the internesting diving behavior of loggerheads nesting in Rethymno. Properties of data loggers differed from those of the satellite transmitters, therefore, results could not be pooled together for analyses. For example, in data loggers I excluded all dives less than 2 m deep because their sensitivity did not make it easy to distinguish between breathing events, dives at very shallow depths, or swimming activities. In contrast, satellite transmitters counted all dives deeper than 1 m. This accounted for the differences in average values for dive depth between the two types of device (Figure 3.2 a and c).

Similarly satellite transmitters were not programmed to record dives lasting less than a minute, while the data logger's settings recorded a dive as any submergence lasting longer than 24 sec. As a result, some diving events were not recorded by the transmitter, which may explain the lower proportion of dives lasting 5 minutes or less in the data logger data (Figure 3.2 b and d). Further, sampling intervals of 24 and 80 seconds allowed for complete diving profiles from the turtles fitted with data loggers. However, sample size for both types of devices was similar (data loggers: n = 18 turtles; satellite transmitters: n = 20 turtles), analysis of data from both provided very similar conclusions, and some of the data complemented each other to provide a clearer description of the sea turtle's diving behavior.

For the most part, female loggerhead turtles remained close to the shore (Panagopoulou, Chapter 2, this thesis), in areas with rock formations and patches of *Posidonia oceanica* sea grass beds (Panagopoulou, Patel and Morreale, pers. observation). The majority of the dives occurred at depths of 5 m or less (data loggers: 58.5%, satellite transmitters: 87.4%), while only a small proportion occurred at depths deeper than 10 m (Data loggers: 10.8%, satellite transmitters: 0.03%).

Contrary to Houghton (2002), who studied the dive behavior of loggerhead turtles nesting in Cyprus, I found only a weak relationship between dive depth and dive duration (Figure 3.6). Therefore I suggest that maximum dive depth was related to bathymetry of the area that the turtles selected to stay in during the internesting period. Selection may have been based on habitat rather than depth (Panagopoulou, Chapter 2, this thesis). Or turtles may have stayed in areas with shallow water because it was warmer.

In contrast, dive duration was an activity indicator for the turtles in this study. Mean dive duration, derived from data loggers, was 11.4 min, with a median of 6.4 min. Overall, dive duration varied among the set histogram bins, with 44.2% (data loggers) and 32.0% (satellite transmitters) of the dives lasting up to 5 minutes, and 20% of the dives having a duration of 20 or more minutes.

More than half the dives performed by loggerheads in Rethymno had a duration of 10 min or longer (data loggers: 55.8%, satellite transmitters: 68.8%), indicating that the turtles may have spent long periods of time remaining submerged and inactive. Short dives less than 5 minutes often are indicative of travelling (e.g. Houghton et al., 2002; Reina et al., 2005; Rice and Balazs, 2008; Cheng, 2009) and/or foraging (e.g. Seminoff, 2006; Fossette et al., 2007; reviewed by Hochscheid, 2014). Longer lasting dives in internesting females are associated with resting on the sea bed (e.g. Minamikawa et al., 1997; Hays et al., 2000; Houghton et al., 2002; Blanco et al., 2012; Fossette et al., 2012; reviewed by Hochscheid, 2014) as well as benthic or mid-water column foraging (e.g. Hochscheid et al., 1999; Fossette et al., 2008; Houghton et al., 2008).

Time at Depth (TAD) histograms derived from satellite transmitters indicated that females spent over 90% of their time at depths shallower than 5 m (Figure 3.13). This accounted for time spent at the surface (e.g. basking), as well as for dives conducted at very shallow depths (between 1 and 5 m). Many of these dives occurring at these depths, especially those occurring at depths of less than 1.5 m were difficult to distinguish from surface activity such as breathing or swimming. Loggerheads nesting in Zakynthos spend long periods of time resting at very shallow depths (2 m deep on average) presumably taking advantage of the higher water temperatures to speed up the egg maturation process

(Schofield et al., 2009; Fossette et al., 2012). It is possible that Rethymno females also engage in similar behavior, remaining submerged for long periods of time at shallow depths.

There was variability in behavior among individual turtles. It is possible that some females trade off preservation of energy in favor of seeking warmer sea water patches at shallow depths as do loggerheads nesting in Zakynthos (Schofield et al., 2009; Fossette et al., 2009) or in other species such as East Pacific leatherbacks (Southwood et al. 1999, Wallace et al., 2005). Many populations of sea turtles fast during the internesting interval using up reserves built up from the time spent at foraging habitats in the period before the breeding season begins (loggerheads in Australia: Limpus and Limpus, 2002; green turtles in Ascension Island: Hays et al., 2002; hawksbills in Brazil: Santos et al., 2010; hawksbills in the Carribean: Walcott et al., 2013; leatherbacks in East Pacific: Reina et al., 2005; leatherbacks in the Carribean: Perrault et al., 2014). However, some sea turtle populations forage if food is available in the internesting habitat (e.g. green turtles in Queensland, Australia: Tucker and Reed, 2001; leatherbacks in the French Guiana: Fossette et al, 2008; Houghton et al., 2008) and loggerheads nesting in Zakynthos apparently forage opportunistically for benthic prey (Schofield et al., 2007), which is also present in the internesting habitat in Rethymno (Zenetos et al., 2005). It is, therefore, possible that the females exhibiting more activity may have engaged in foraging behavior to replenish their energy reserves during the internesting interval. However, this is in contrast to their counterparts, the majority of which may have selected to conserve energy by resting.

There was variability in behavior during the day. Mean dive duration was significantly higher from 03:00 to 15:00 than during the later afternoon (15:00) through 03:00 (data loggers). Both data logger and satellite transmitter data indicated that number of dives performed per four-hour period was significantly lower in periods between 11:00 and 15:00 (data loggers) and between 11:00 and 19:00 (satellite transmitters). Time-At-Depth (TAD) data derived from satellite transmitters indicated that between 11:00 and 19:00 females spent > 95% of their time in the top 5 m of the water column. The lower number of dives, combined with the longer dive duration during those daylight hours, is suggestive of females spending long periods of time submerged or resting close to or at the surface, possibly basking at the water surface. This possible explanation has some merit because loggerhead turtles can raise their body temperature by as much as 4°C by exposing their carapace to the sun (Spotila and Standora, 1985) and they also spend prolonged periods of time at the surface at times when the sun is at its highest such that they maximize heat gain (Hochscheid et al., 2010). Mean temperatures experienced by females were at their highest during the period between 11:00 and 19:00 (Figure 3.14), therefore loggerheads could be taking advantage of the solar energy to help speed-up the maturation of the eggs. Further, sea turtles select for habitat type (Hart et al., 2010; Walcott et al., 2014; Panagopoulou, Chapter 2, this thesis) rather than depth. Therefore, it may be possible that the turtles in this study occupied these shallow depths because of the habitat types present that include patches of *Posidonia oceanica* and rock formations that were suitable resting locations and offered additional benefits such as protection from potential predators and “hopeful” males seeking to mate with them. However, the resolution of the data loggers and the satellite transmitters may have failed to highlight other possible behaviors occurring at the top 3 meters of the water column that include breathing events (Reina et al., 2005), subsurface swimming (Reina et al., 2005; Seminoff et al., 2006, Rice and Balazs 2008), or foraging activity (Seminoff et al., 2006).

Conclusions

Results of this study show that dive depth, dive duration, time at depth and number of dives can be good proxies to study the behavior of sea turtles during the internesting interval. My findings support the hypothesis that the diving behavior of Rethymno loggerheads during the internesting interval is driven by energy optimization strategies. In general, females appeared to focus their energy reserves towards the preparation of subsequent clutches, although I observed significant variability in behavior among individual turtles and during different times of day. Some females exhibited more active behavioral patterns than others, however many remained largely inactive during the internesting interval, spending long periods of time either resting on the sea bed or near the sea surface. That behavior was consistent with most other findings for loggerhead turtles in the Mediterranean (Houghton et al., 2002; Schofield et al., 2009b; Fossete et al., 2012; Backof, 2013) and for other sea turtle species (e.g. green turtles: Hays et al., 1999; East Pacific greens: Blanco et al., 2012; East Pacific leatherbacks: Shillinger et al., 2010; hawksbills: Walcott et al., 2013). The findings of this study indicate that turtles may be highly vulnerable while spending internesting in shallow waters, especially since they appear to select for habitats close to the shore

(Panagopoulou, Chapter 2, this thesis). This information needs to be taken into account when developing an effective management plan for the area.

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Tables and Figures

Table 3.1. Deployment data for the 18 retrieved Time-Depth data loggers. All individuals were assessed to be inter-nesting through ultrasonography. † indicates the females that were also satellite-tracked.

Turtle ID	**CCL (cm)**	**Date deployed**	**Date retrieved**	**Observed inter-nesting period (days)**	**Estimated number of Inter-nesting intervals**
RET 01	80.0	13/07/2010	24/07/2010	11	1
RET 02	85.0	05/07/2010	18/07/2010	13	1
RET 03	85.0	10/07/2010	24/07/2010	14	1
RET 04†	84.5	05/07/2011	19/07/2011	14	1
RET 05†	75.5	08/07/2011	21/07/2011	13	1
RET 06†	82.0	03/07/2011	16/07/2011	13	1
RET 07†	84.5	04/07/2011	19/07/2011	15	1
RET 08	89.5	12/06/2012	28/06/2012	16	1
RET 09	78.0	06/07/2012	18/07/2012	12	1
RET 10	79.5	14/06/2012	29/06/2012	15	1
RET 11	95.5	13/06/2012	27/06/2012	14	1
RET 12	83.0	14/06/2012	09/07/2012	25	2
RET 13	78.5	18/06/2012	01/07/2012	13	1
RET 14	86.0	12/06/2012	26/06/2012	14	1
RET 15	75.5	16/06/2012	26/07/2012	40	3
RET 16	89.0	18/06/2012	02/07/2012	14	1
RET 17	86.0	21/06/2012	07/07/2012	16	1
RET 18	76.0	28/06/2012	10/07/2012	12	1

Table 3.2. Deployment data for the 20 satellite-tracked turtles. All were assessed to be inter-nesting at the time of deployment. I, II and III refers to equipment replaced on the same female when she was re-encountered after approx. two weeks. † indicates the simultaneous attachment of a transmitter and data logger. ‡ indicates females that remained resident within the continental shelf of Crete after the nesting season was complete. * indicates interrupted transmission of data, due to malfunction and/or removal of the tag by third parties.

TURTLE ID	CCL (cm)	Deployment #	Date Deployed	Date Retrieved	Date of estimated departure from site (or of last transmission)	Days of observation	Estimated Number of Inter-nesting Intervals
Turtle 01	78.5	I	01/06/2011	16/06/2011		15	1
		II	16/06/2011	30/06/2011		15	1
		III	30/06/2011		24/07/2011	24	1
Turtle 02		I	05/06/2011		18/07/2011‡	43	2 - 3
Turtle 03	71.0	I	06/06/2011	22/06/2011		16	1
		II	23/06/2011	08/07/2011		15	1
Turtle 04	81.0	I	07/06/2011	10/07/2011		33	2
		II	10/07/2011		30/07/2011	20	1
Turtle 05	82.0	I	08/06/2011	23/06/2011		15	1
		II	24/06/2011	08/07/2011		14	1
		III	10/07/2011		14/08/2011	35	2
Turtle 06	90.0	I	11/06/2011		22/06/2011*	11	1
Turtle 07	85.0	I	12/06/2011	28/06/2011	No transmitter	16	1
Turtle 08	85.0	I	13/06/2011	26/06/2011		13	1
		II	28/06/2011	12/07/2011		14	1
		III	12/07/2011	25/07/2011	27/07/2011	13	1

Table 3.2. (cont.)

TURTLE ID	CCL (cm)	Deployment #	Date Deployed	Date Retrieved	Date of estimated departure from site (or of last transmission)	Days of observation	Estimated Number of Inter-nesting Intervals
Turtle 09	86.0	I	16/06/2011	01/07/2011		15	1
		II	03/07/2011		16/07/2011*	13	1
Turtle 10†	82.0	I	18/06/2011	03/07/2011		15	1
		II	03/07/2011†	16/07/2011†	No transmitter	13	1
Turtle 11†	84.5	I	19/06/2011	03/07/2011		14	1
		II	05/07/2011	19/07/2011†	20/07/2011	14	1
Turtle 12†	75.5	I	21/06/2011	08/07/2011		17	1
		II	08/07/2011	24/07/2011†		16	1
		III	24/07/2011		05/08/2011‡	12	1
Turtle 13	75.0	I	21/06/2011		15/08/2011‡	55	2 - 3
Turtle 14	81.0	I	22/06/2011		10/07/2011	18	1
Turtle 15	91.0	I	25/06/2011		12/07/2011	17	1
Turtle 16	82.5	I	26/06/2011		29/07/2011	33	2
Turtle 17	87.0	I	30/06/2011		17/07/2011	17	1
Turtle 18†	84.5	I	04/07/2011	19/07/2011†		15	1
Turtle 19	78.0	I	07/07/2011		14/08/2011‡	38	2 - 3
Turtle 20	90.0	I	12/07/2011		14/08/2011	33	1

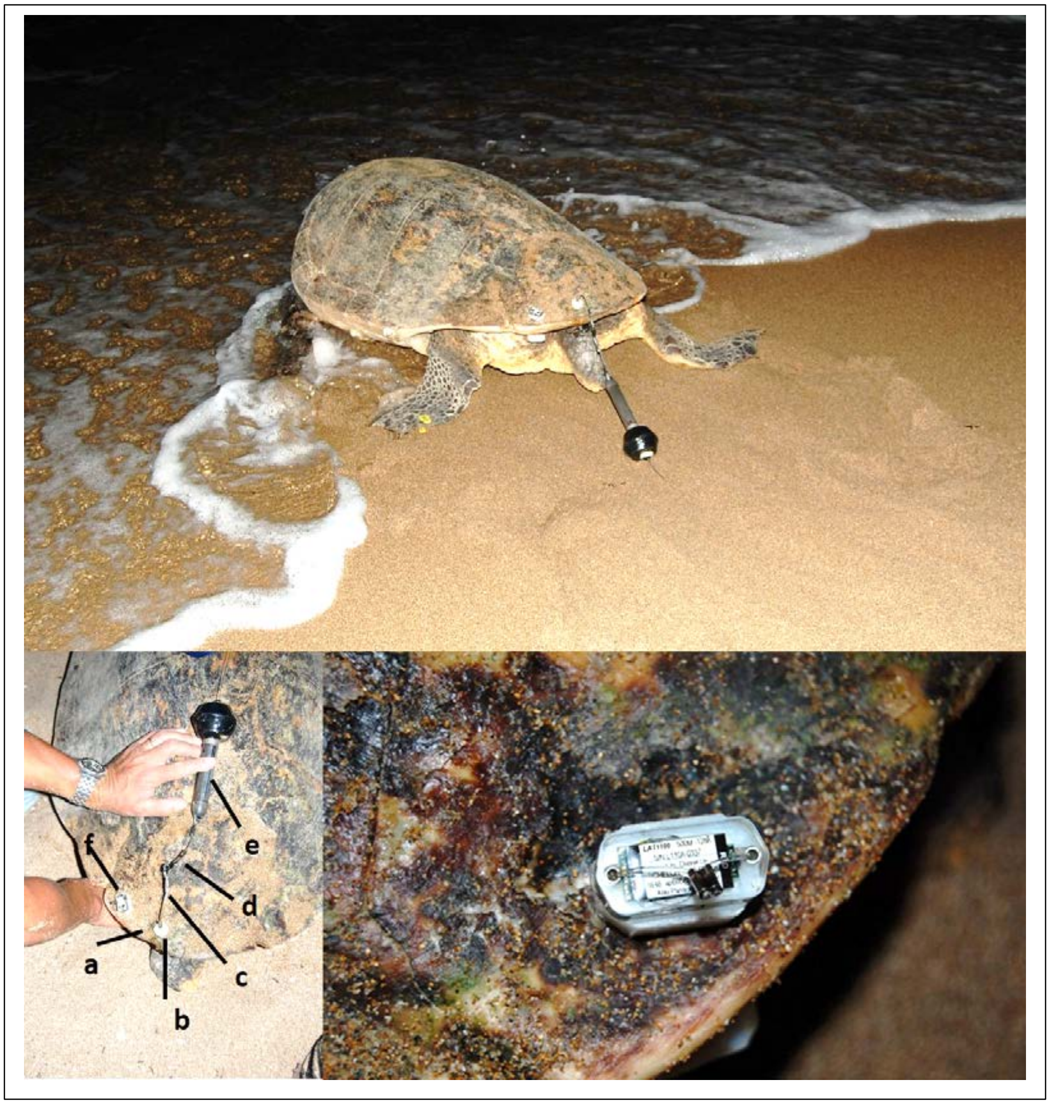


Figure 3.1. Satellite transmitter and data logger attachment on a loggerhead turtle in Rethymno. (a) Left supracaudal scute. (b) Upper plastic top button. (c) 172 kg test monofilament fishing line. (d) Corrosive link with metallic crimps and swivel. (e) Satellite transmitter (Mk 10 Pop-up Archival Tag). (f) Data logger (LOTEK 1100 Series).

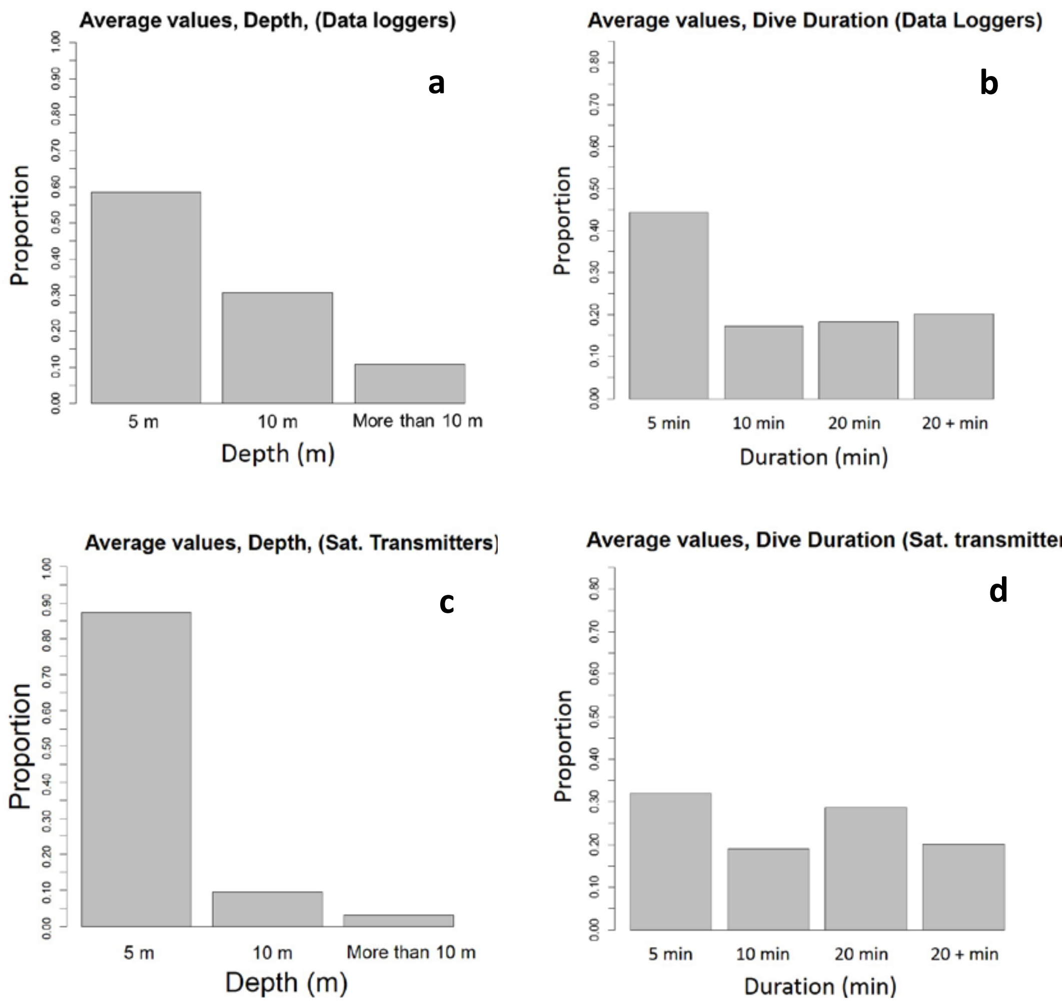


Figure 3.2. (a, b). Average values for dive depth, and duration, data loggers. Values were derived from 18 retrieved loggers. A dive was defined as a submergence event occurring deeper than 2 m, regardless of the duration. Dives were summarized into three bins of 5 m, 10 m. 10 m and more than 10 m for depth and 5 min, 10 min, 20 min and more than 20 min. **(c, d). Average values for dive depth and dive duration, satellite transmitters.** Values were derived from a subset of all recorded interesting intervals, including a single interval per female turtle. A dive was pre-programed to be a submergence event deeper than 1 m and lasting longer than 1 min.

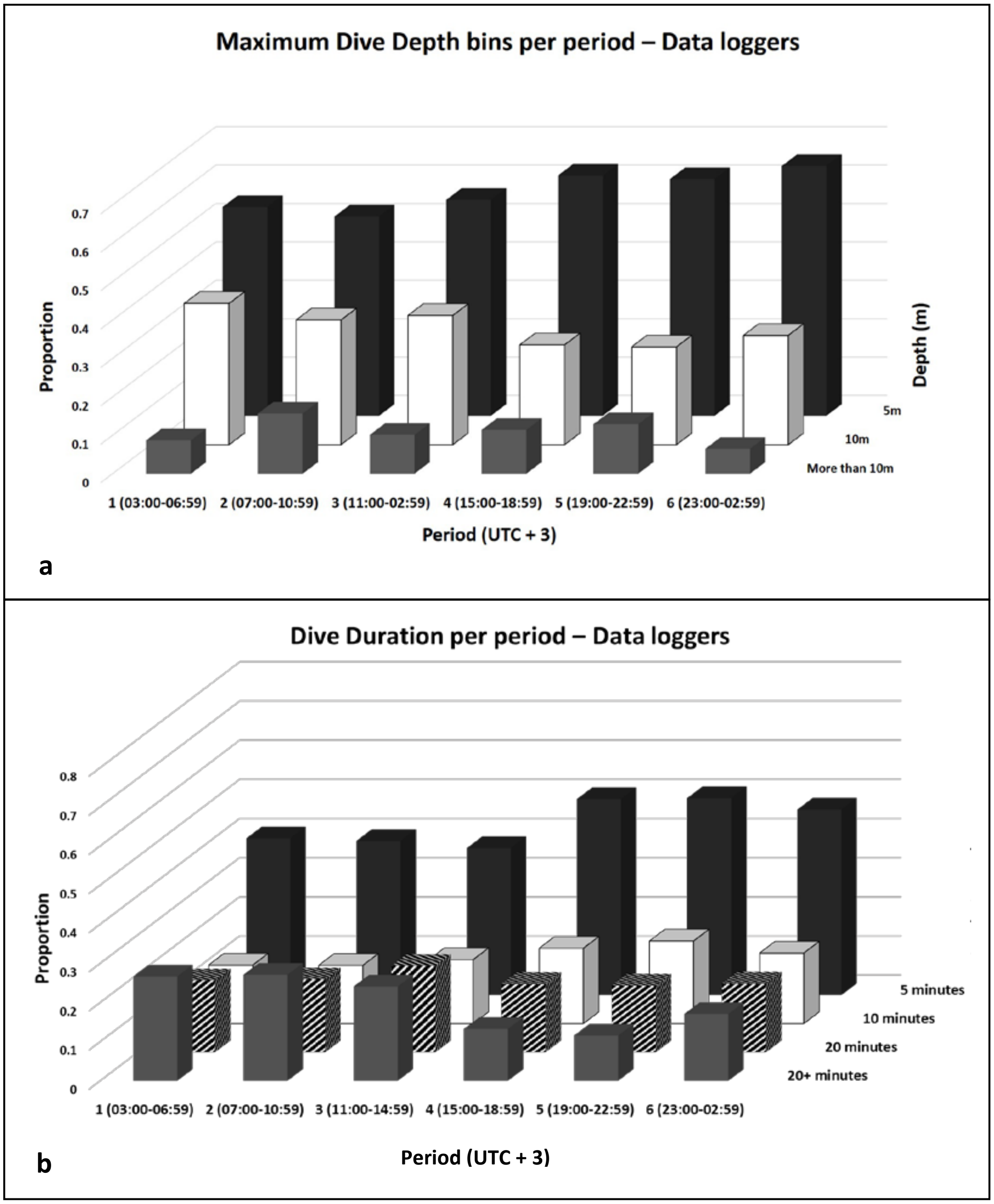


Figure 3.3. a) Dive depth per six-hour period derived from data loggers. Bins for depth were merged into three: 5 m, 10 m and more than 10 m **b) Dive duration per six hour period.** Bins for dive duration were merged into four: 5 min, 10 min, 20 min, more than 20 min. Periods were converted to the time zone experienced by the animal (UTC + 3 hours).

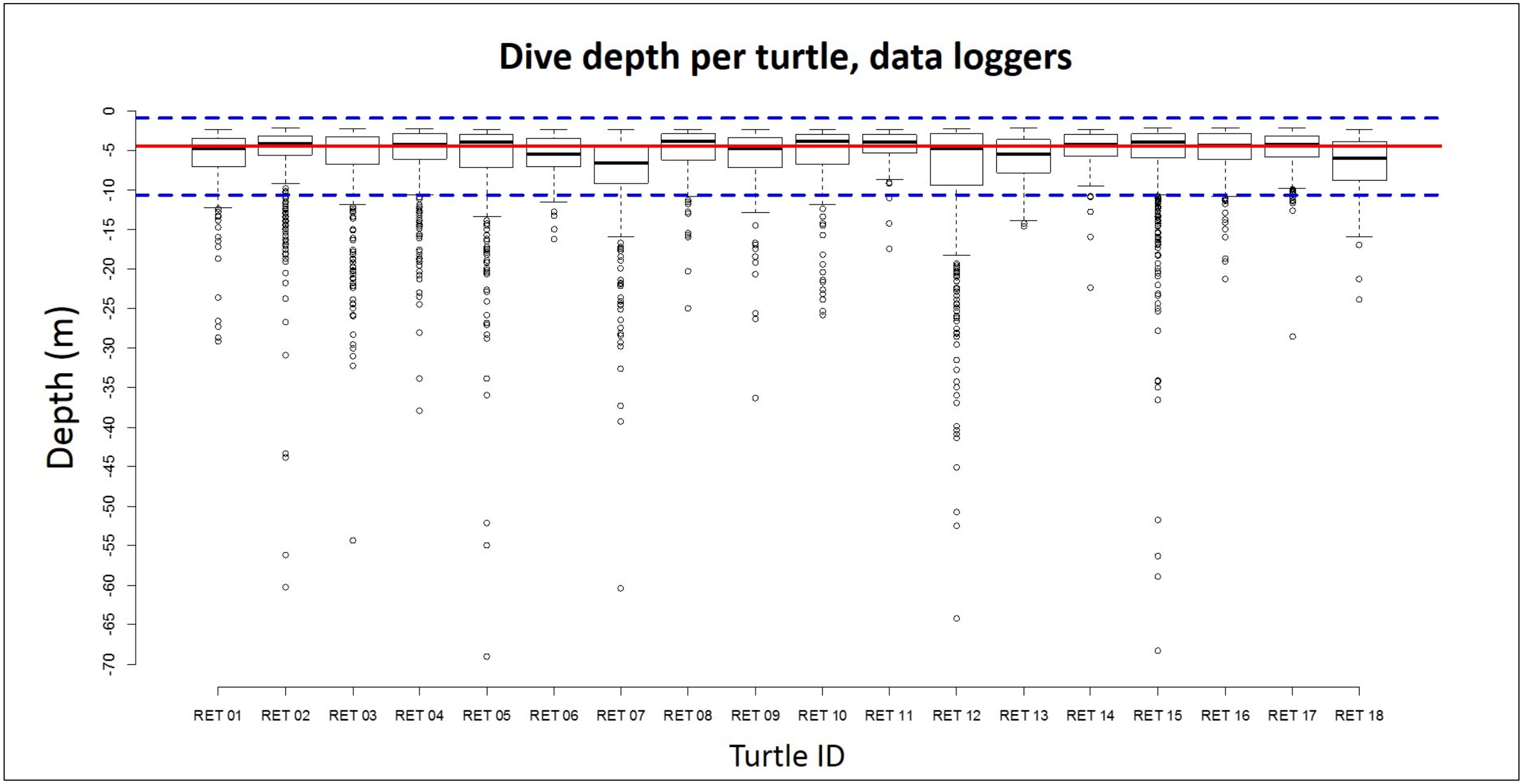


Figure 3.4: Dive depth summary data from 18 data loggers retrieved in Rethymno. Red line indicates the median value for all turtles (-4.4 m). Blue dashed lines indicate the standard deviation (SD) from the mean (-5.8 m). Black horizontal bars = median depth for each turtle; box = 50% of the data; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e. observations farther than 1.5 times the interquartile range.

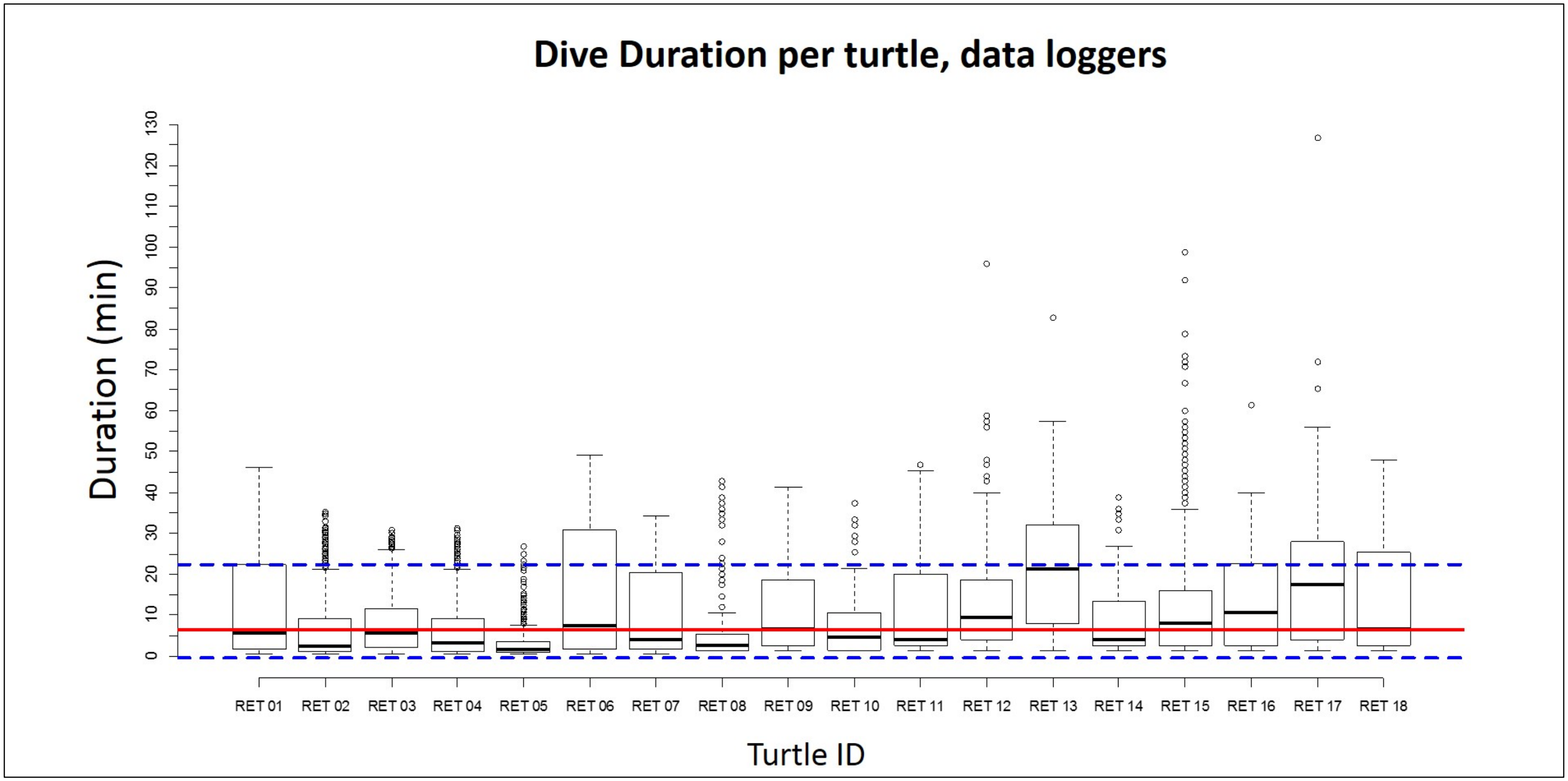


Figure 3.5. Dive duration summary data from 18 data loggers retrieved in Rethymno. Red line indicates the median value for all turtles (6.4 min). Blue dashed lines indicate the standard deviation (SD) from the mean (11.4 min). Black horizontal bars = median duration for each turtle; box = 50% of the data; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e. observations farther than 1.5 times the interquartile range.

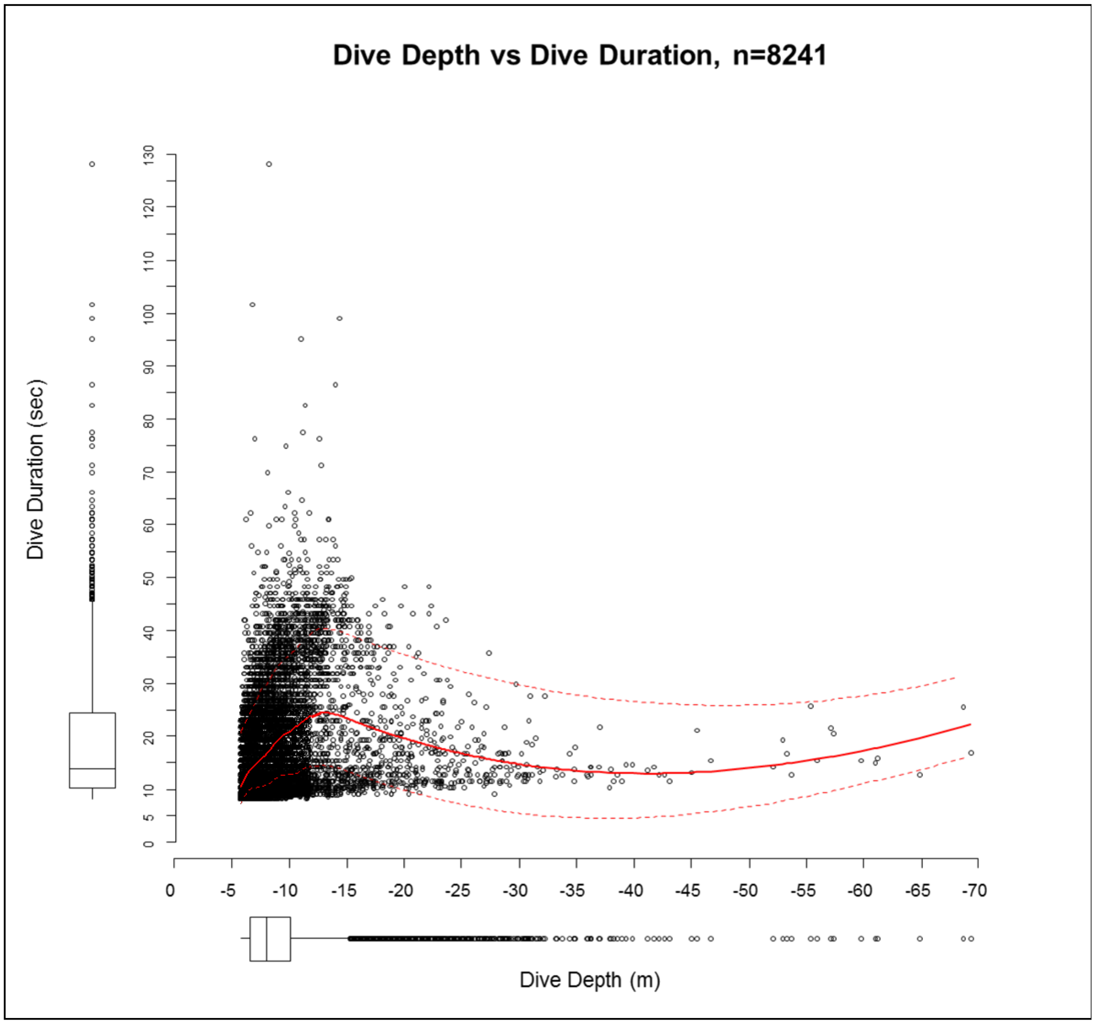


Figure 3.6. Depth vs Duration for biological dives recorded by data loggers. Red straight line indicates the locally weighted smoothing trend line (loess) with confidence intervals indicated by red dashed lines. Boxplots the distribution for dive depth (x axis) and duration (y axis). The black horizontal bars on the boxplots indicate the median values. Boxes = 50% of the data; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e observations farther than 1.5.times the interquartile range.

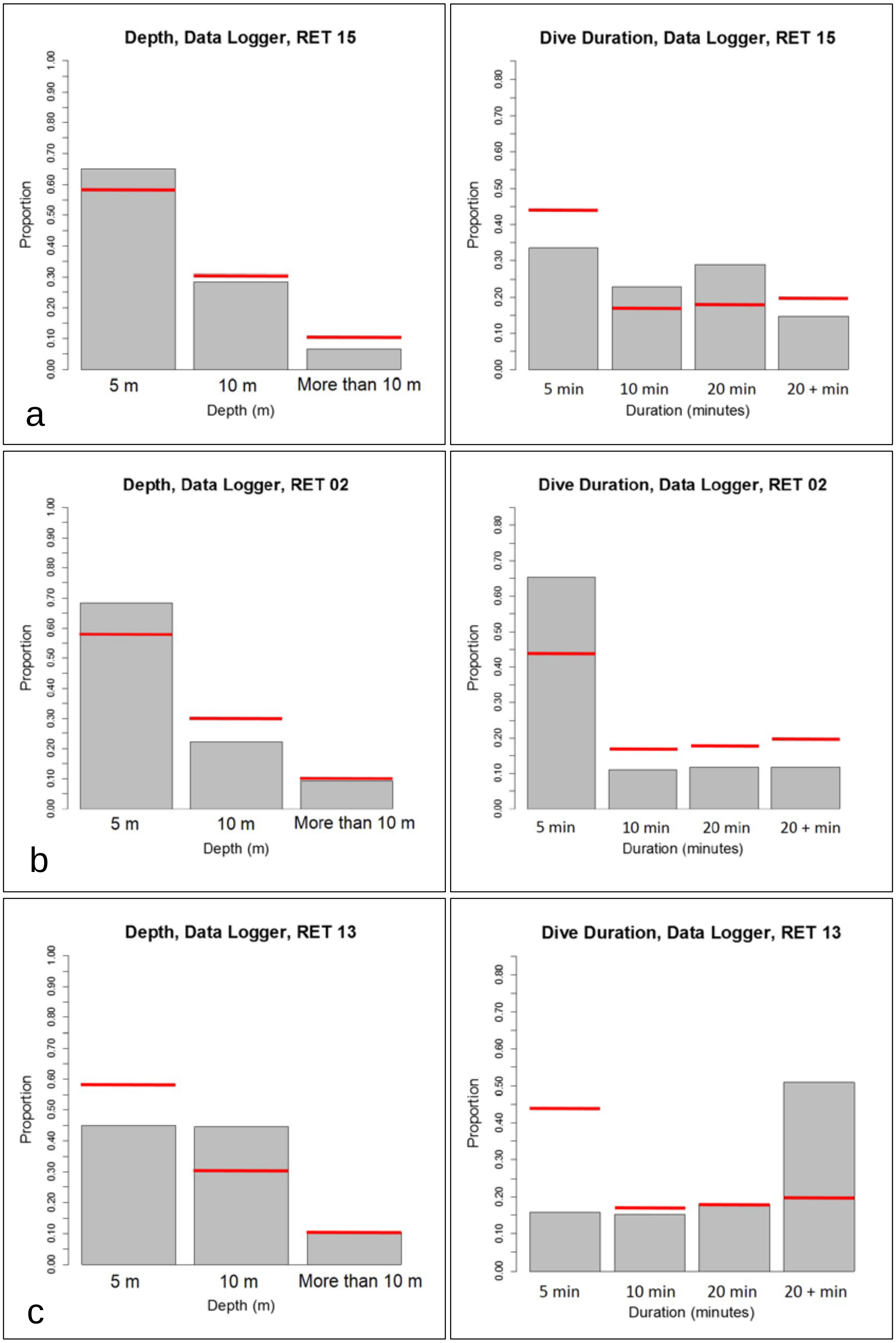

Depth, Data Logger, RET 15
Proportion
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
5 m
10 m
More than 10 m
Depth (m)
a
Dive Duration, Data Logger, RET 15
Proportion
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
5 min
10 min
20 min
20 + min
Duration (minutes)
Depth, Data Logger, RET 02
Proportion
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
5 m
10 m
More than 10 m
Depth (m)
b
Dive Duration, Data Logger, RET 02
Proportion
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
5 min
10 min
20 min
20 + min
Duration (minutes)
Depth, Data Logger, RET 13
Proportion
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
5 m
10 m
More than 10 m
Depth (m)
c
Dive Duration, Data Logger, RET 13
Proportion
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
5 min
10 min
20 min
20 + min
Duration (minutes)

Figure 3.7. a) Internesting behavior, RET 15 (data logger). This female exhibited a less active behavioral pattern by undergoing more dives at depths less than 5 m deep (std. residuals from x^2 test: 0.56, 0.75, -2.00) and more 10 min and 20 min dives (std. residuals from x^2 test -10.40, 7.23, 13.36, -6.80). **b) Internesting behavior, RET 02 (data logger).** This female was more active, undergoing more dives at depths < 5 m (std. residuals from x^2 test: 5.69, -5.17, -1.35) and more dives shorter than 5 min (std. residuals from x^2 test 12.06, -4.65, -4.76, -5.94). **c) Internesting behavior, RET 13 (data logger).** This female exhibited a low activity behavioral pattern by engaging in significantly fewer dives less than 5 m deep (std. residuals from x^2 test: -5.62, -6.16, -0.24) and significantly more dives lasting 20 minutes (std. residuals from x^2 test -11.75, -1.21, -0.12, 15.77). Red lines indicate the average values for depth (5 m: 0.585, 10 m: 0.307, more than 10 m: 0.108) and duration (5 min: 0.442, 10 min: 0.173, 20 min: 0.183, 20+ min: 0.202).

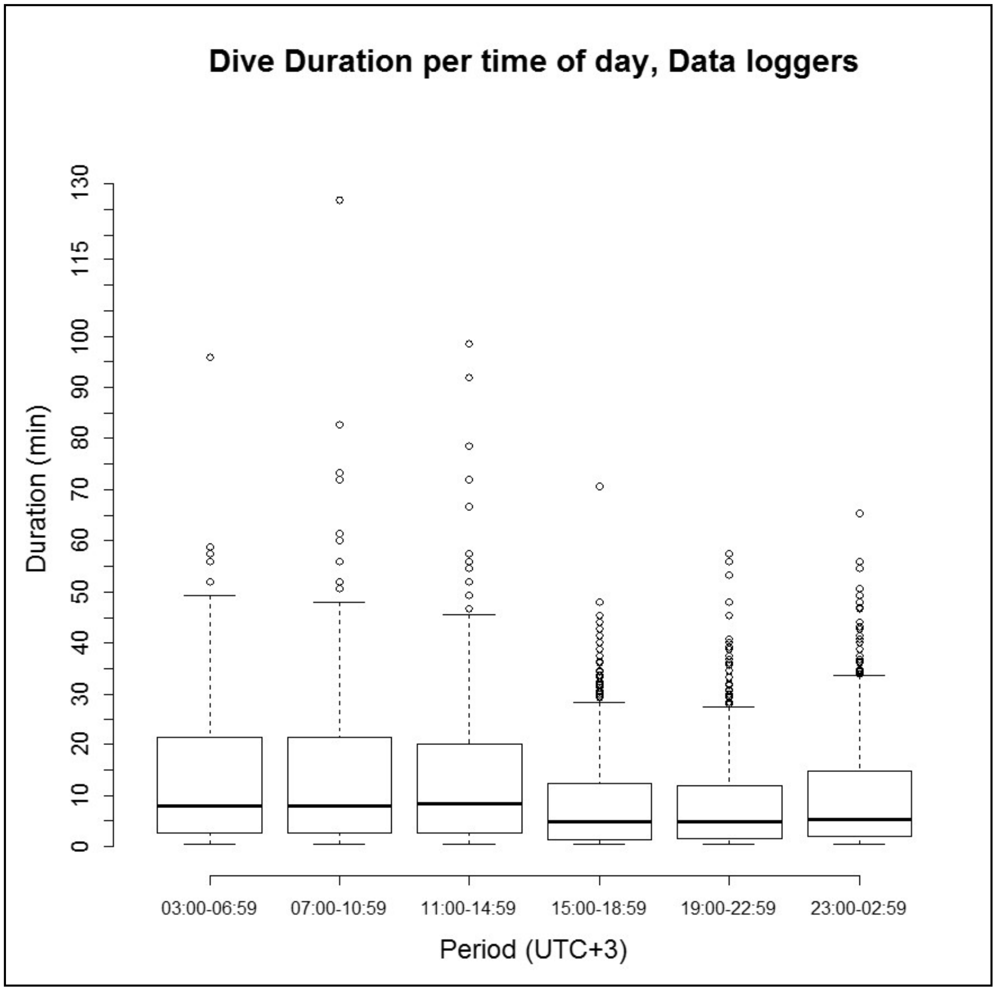


Figure 3.8. Mean dive duration per time of day (data loggers). Mean and SD values were estimated at 13.1 ± 12.9 min (Period 1), 13.0 ± 12.9 (Period 2), 12.8 ± 12.6 min (Period 3), 8.8 ± 9.7 min (Period 4), 8.2 ± 8.8 min (Period 5) and 9.7 ± 10.3 min (Period 6). The black horizontal lines within each box indicate the median duration for each period; boxes indicate 50% of the dive duration values; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e observations farther than 1.5.times the interquartile range.

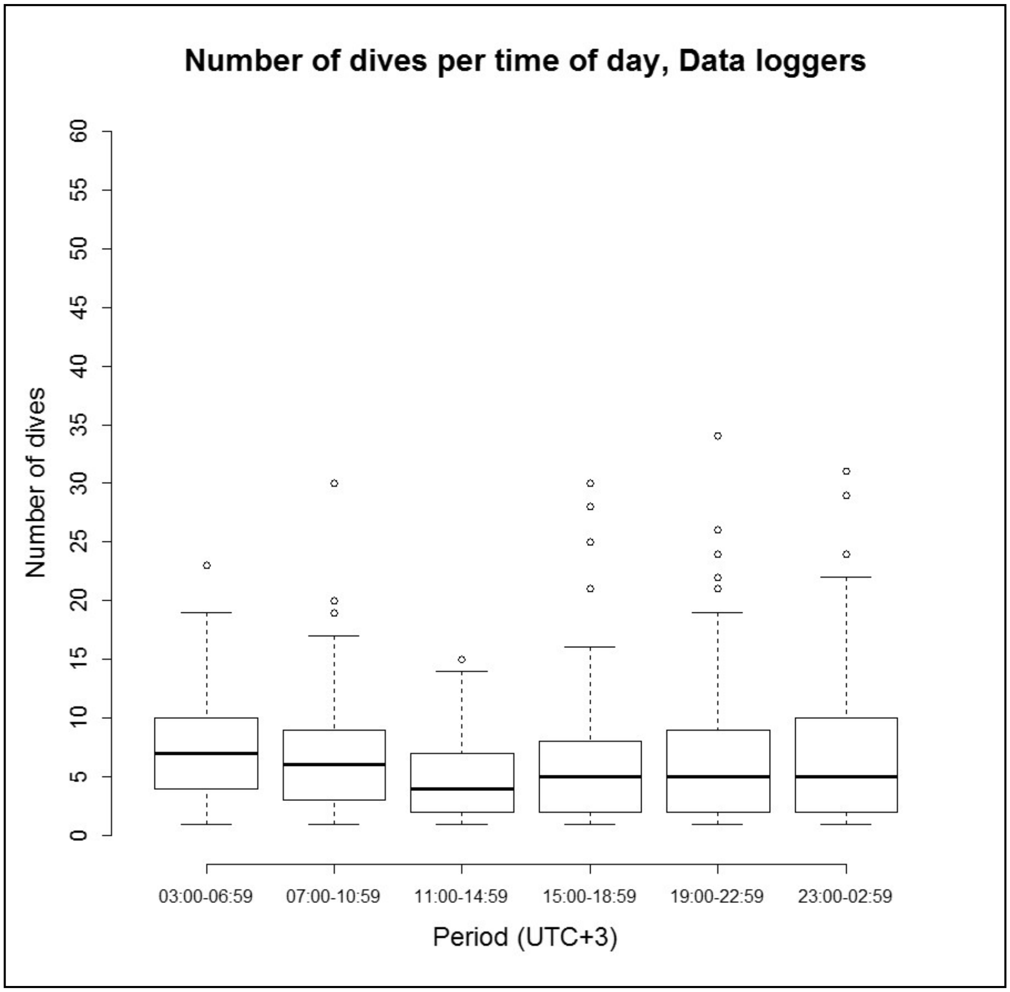


Figure 3.9. Mean number of dives per time of day (data loggers). Mean and SD values were estimated at 7.0 ± 4.2 dives (Period 1), 6.8 ± 4.4 dives (Period 2), 5.0 ± 3.7 dives (Period 3), 5.7 ± 4.5 dives (Period 4), 6.7 ± 5.3 dives (Period 5) and 6.8 ± 5.4 dives (Period 6). The black horizontal lines within each box indicate the median duration for each period; boxes indicate 50% of the dive duration values; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e observations farther than 1.5.times the interquartile range.

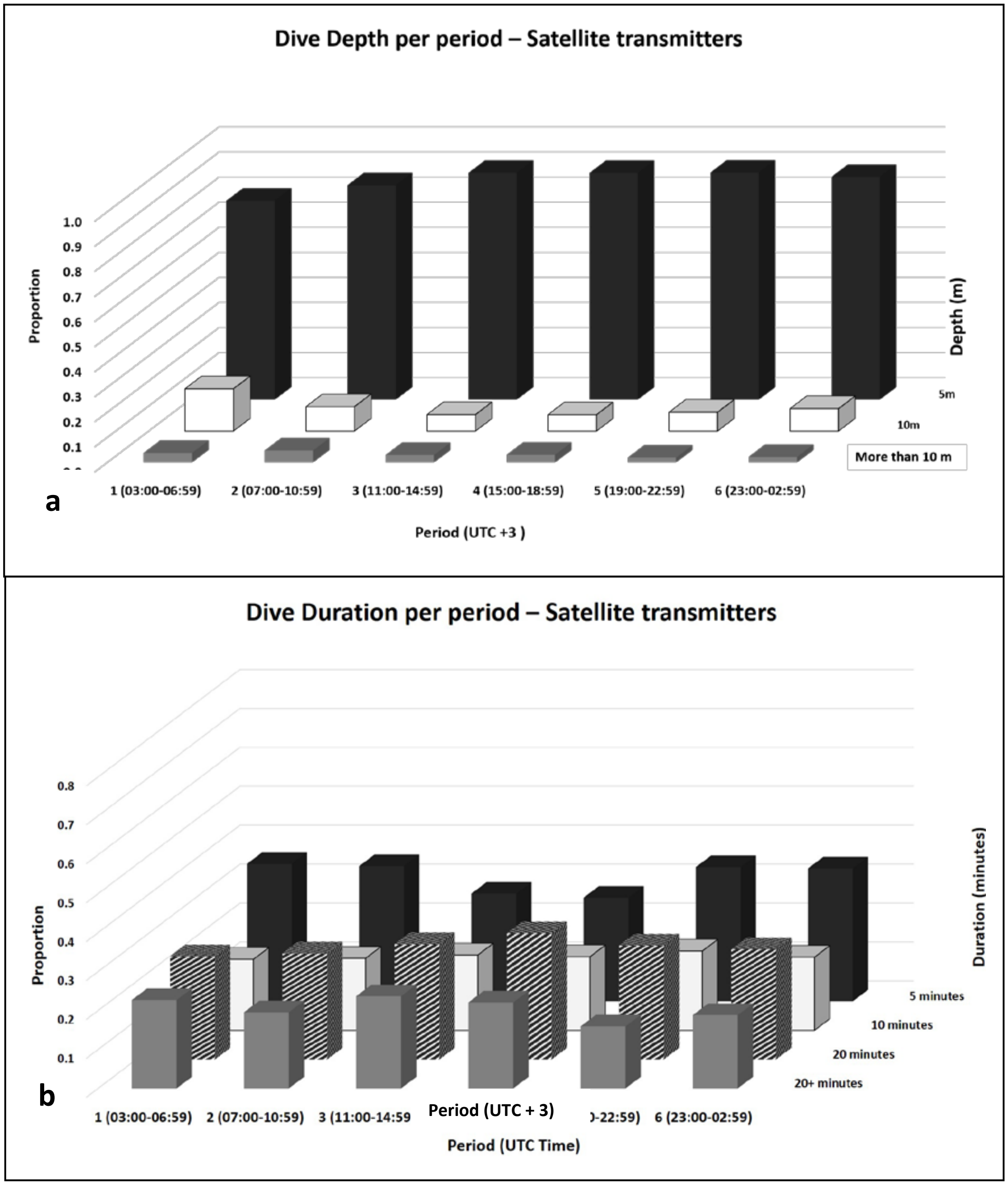


Figure 3.10. a) Dive depth per six-hour period derived from satellite transmitters. Bins for depth were merged into three: 5 m, 10 m and more than 10 m **b) Dive duration per six hour period derived from satellite transmitters.** Bins for dive duration were merged into four: 5 minutes, 10 minutes, 20 minutes, more than 20 minutes . Periods were converted to the time zone experienced by the animal (UTC + 3hrs).

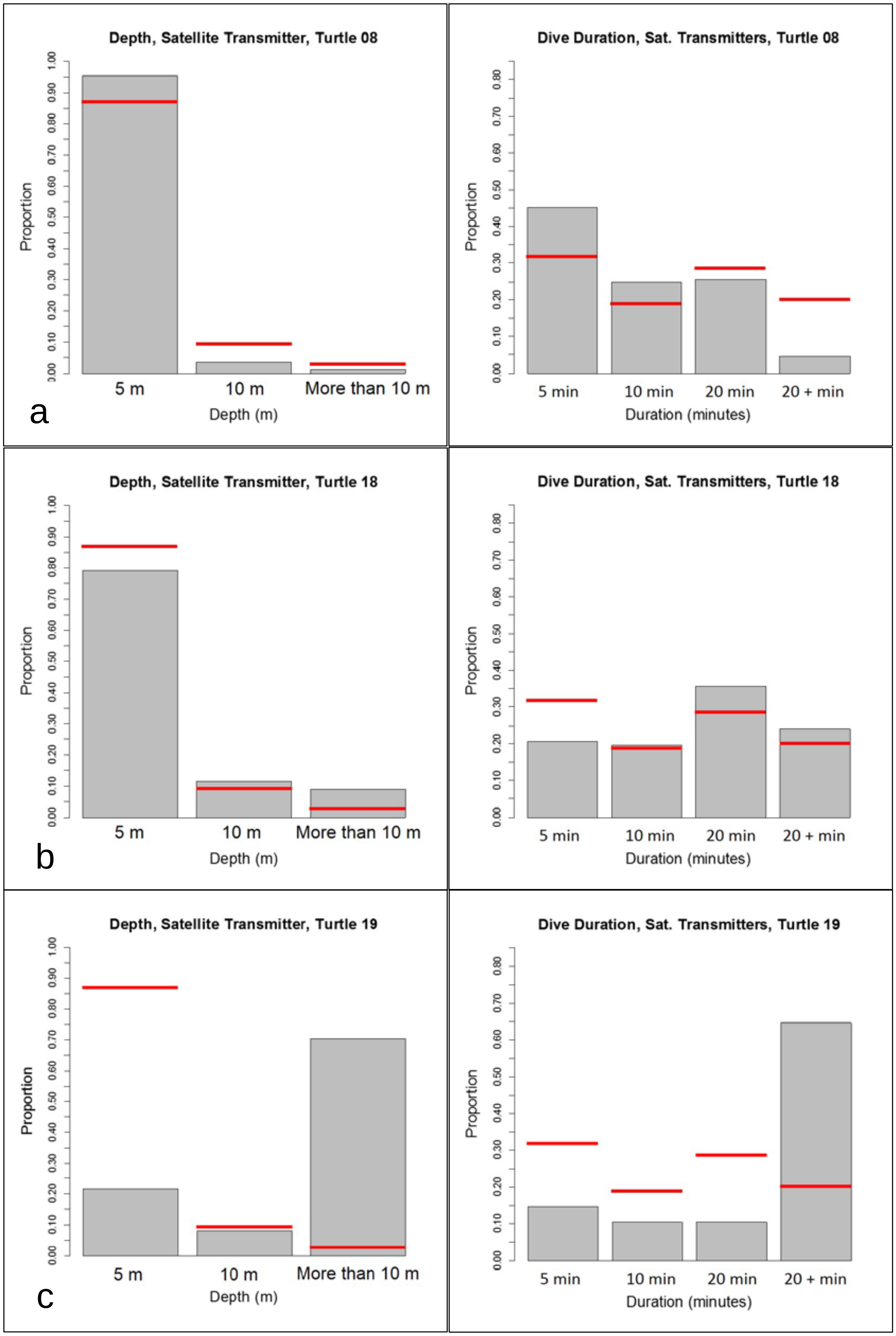

Depth, Satellite Transmitter, Turtle 08
Proportion
5 m
10 m
More than 10 m
Depth (m)
a
Dive Duration, Sat. Transmitters, Turtle 08
Proportion
5 min
10 min
20 min
20 + min
Duration (minutes)
Depth, Satellite Transmitter, Turtle 18
Proportion
5 m
10 m
More than 10 m
Depth (m)
b
Dive Duration, Sat. Transmitters, Turtle 18
Proportion
5 min
10 min
20 min
20 + min
Duration (minutes)
Depth, Satellite Transmitter, Turtle 19
Proportion
5 m
10 m
More than 10 m
Depth (m)
c
Dive Duration, Sat. Transmitters, Turtle 19
Proportion
5 min
10 min
20 min
20 + min
Duration (minutes)

Figure 3.11. a) Internesting behavior, Turtle 08 (satellite transmitter). This female exhibited an active behavioral pattern by undergoing more dives at depths less than 5 m deep (std. residuals from x^2 test: 10.90,-9.29, -5.16) and more dives lasting 5 min or less (std. residuals from x^2 test 12.67, 6.78, -3.18, -17.77). **b) Turtle 18 (satellite transmitter).** This female was less active, undergoing fewer dives at depths < 5 m (std. residuals from x^2 test: -8.87, 2.64, 12.53) and more dives lasting 20 min or more (std. residuals from x^2 test -8.90, 0.48, 5.65, 3.49). **c) Turtle 19 (satellite transmitter).** This female exhibited the highest deviation from the average values both for depth by conducting significantly more dives at depths deeper than 10 m (std. residuals from x^2 test: -20.91, -0.50, 40.90) and dive duration, with more dives lasting more than 20 min (std. residuals from x^2 test –4.02, -2.39, -4.39, 11.95). Red lines indicate the average values for depth (5 m: 0.874, 10 m: 0.095, more than 10 m: 0.031) and duration (5 min: 0.320, 10 min: 0.190, 20 min: 0.287, 20+ min: 0.203).

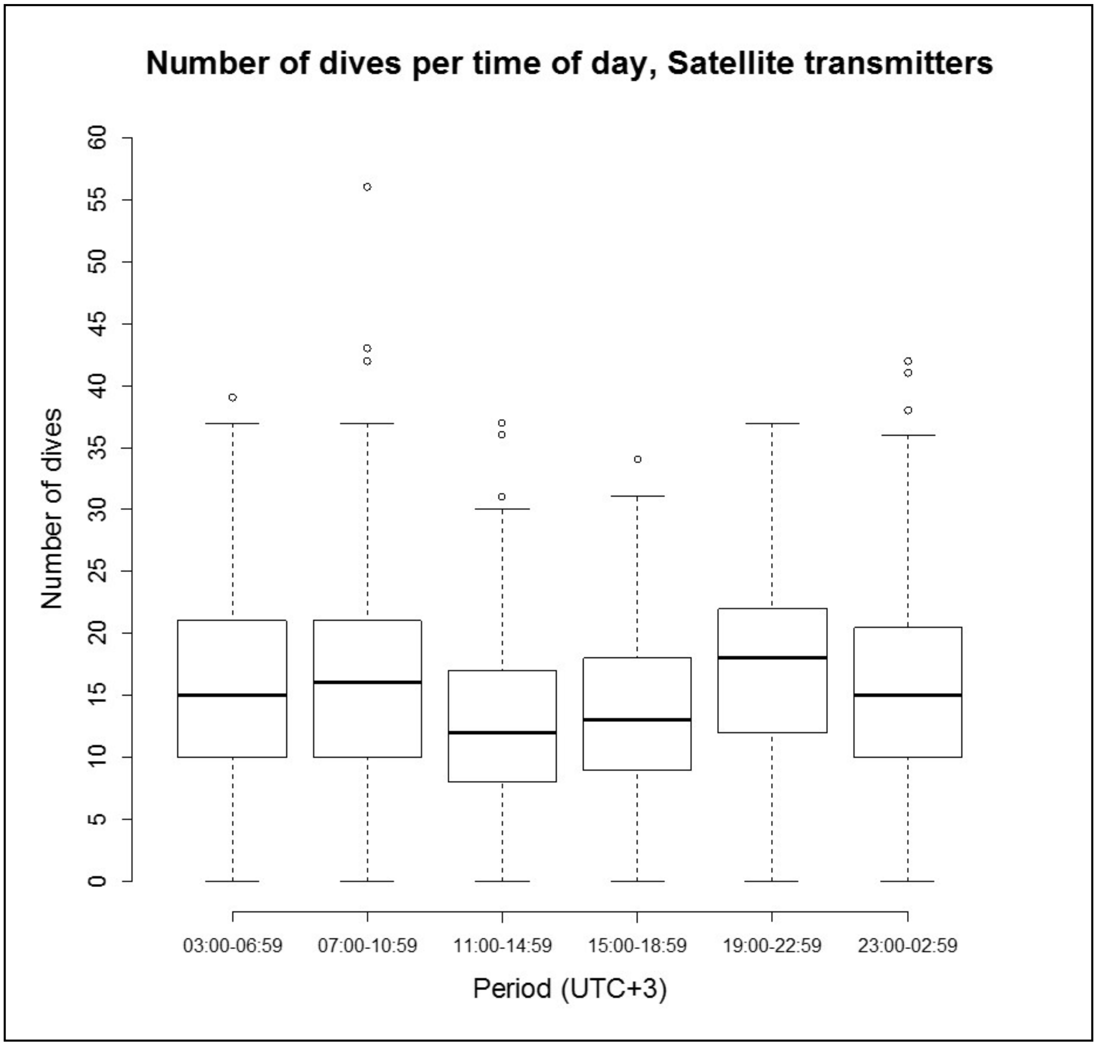


Figure 3.12. Mean number of dives per time of day, (satellite transmitters). Mean and SD values were estimated at 15.9 ± 8.1 dives (Period 1), 16.0 ± 8.2 dives (Period 2), 13.0 ± 6.7 dives (Period 3), 14.1 ± 7.4 dives (Period 4), 17.3 ± 7.1 dives (Period 5) and 16.2 ± 8.1 dives (Period 6). The black horizontal lines within each box indicate the median duration for each period; boxes indicate 50% of the dive duration values; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e observations farther than 1.5.times the interquartile range.

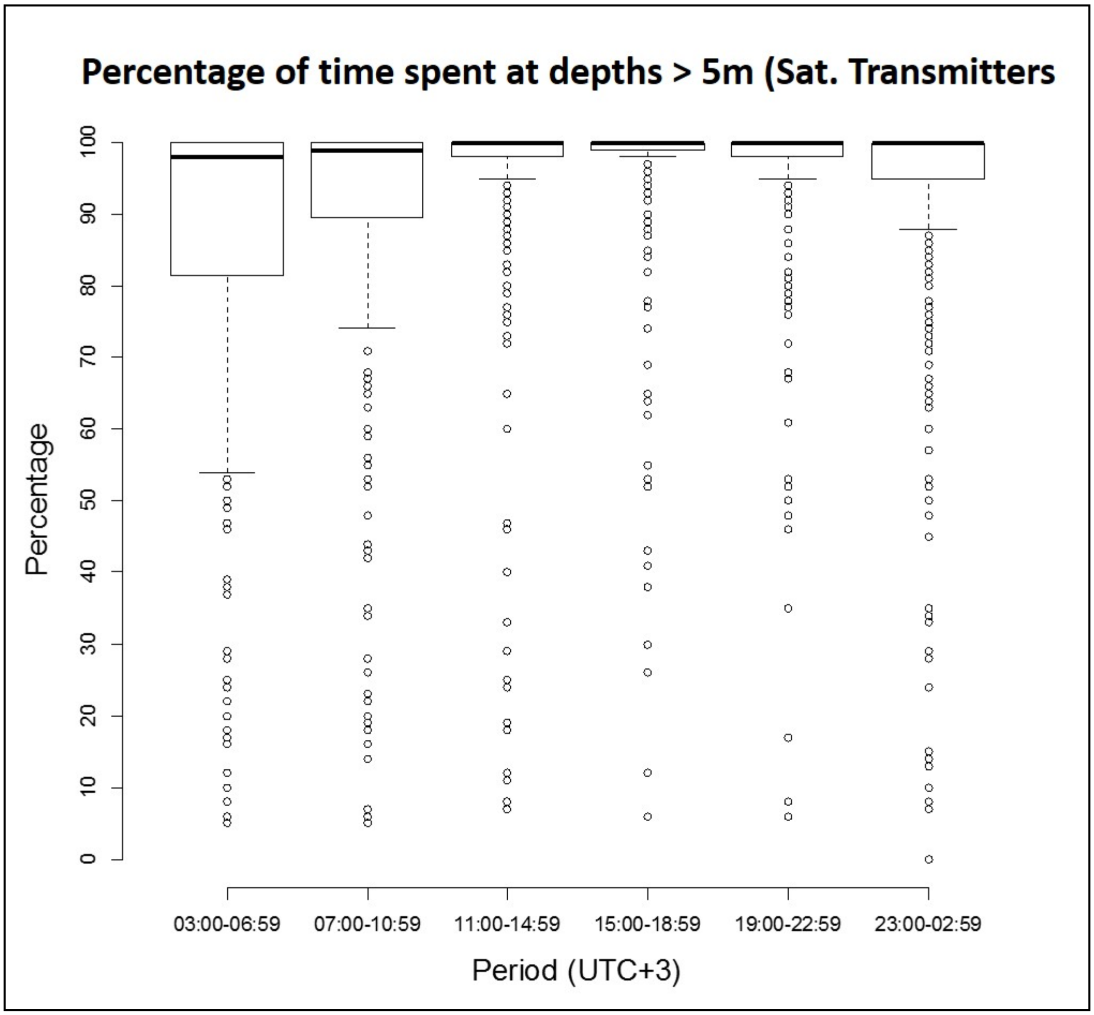
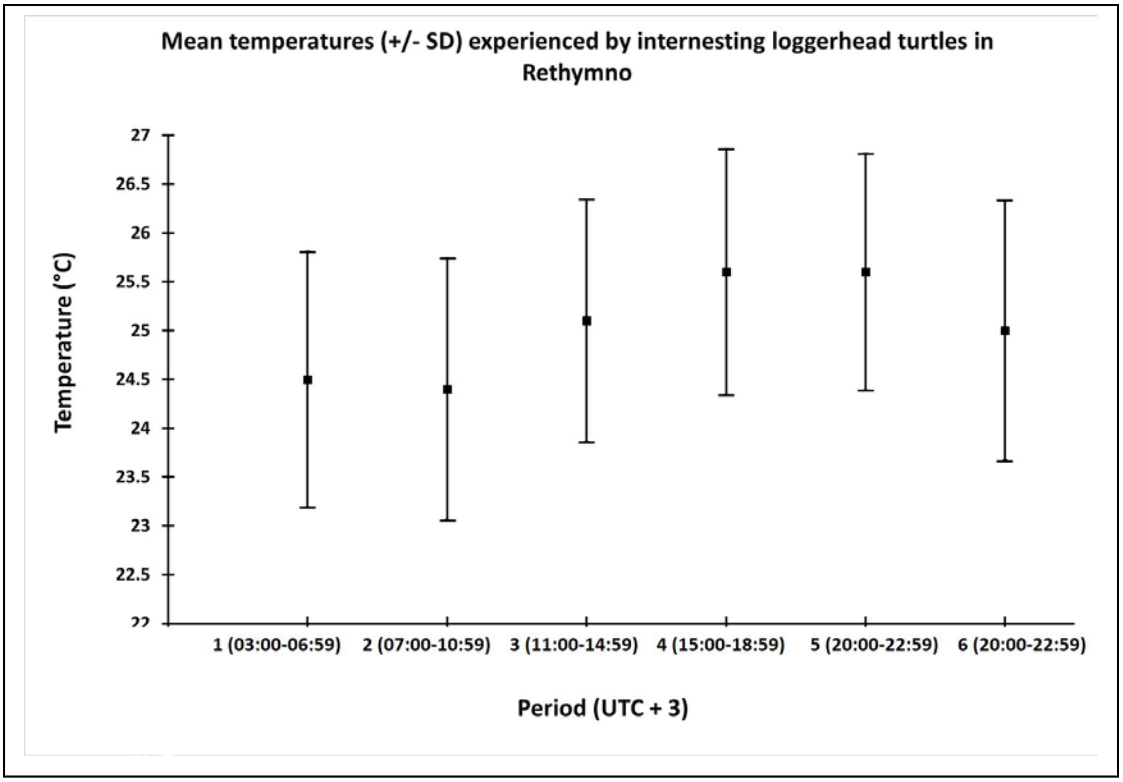


Figure 3.13. Percentage of time spent at depths of < 5m for each period, (satellite transmitters). Females appear to be spending nearly 100% of their time in the top 5 m of the water column during periods 3 (11:00 – 02:59), 4 (15:00 – 18:59) and 5 (19:00 – 22:59). The black horizontal lines within each box indicate the median duration for each period; boxes indicate 50% of the dive duration values; whiskers = range of observations within 1.5 times the interquartile range from the edge of the box; circles indicate the outliers, i.e observations farther than 1.5.times the interquartile range.



3.14. Mean temperatures experienced by loggerhead turtles nesting in Rethymno. Error bars represent +/- SD. Mean temperatures ranged from 24.4 to 25.6 °C.

Chapter 4: Untangling fishermen-turtle relationships: Investigating perceptions of small-scale fishermen in Crete about their interactions with sea turtles.

Introduction

In recent years it has become apparent that small-scale fisheries may be responsible for high numbers of by-catch that affect large marine vertebrates such as sharks, cetaceans, monk seals and sea birds (Stevens et al., 2000; Lewison et al., 2004a; Reed et al., 2006; Lewison et al., 2014; Anderson et al., 2011; Croxall et al., 2012). The associated mortality has caused declines in populations and has become a serious challenge for the conservation of many large marine vertebrates (Hall, 2000; Lewison et al., 2004a; Lewison et al., 2014). It has also become a prominent management issue for small-scale fishermen (Kelleher, 2005).

The Mediterranean Sea is one of the most intensely fished regions in the world and is therefore an area with high incidents of accidental captures of turtles in fishing gear, estimated at 130,000 - 150,000 per year, the majority of which are loggerhead turtles (*Caretta caretta*) (Lewison et al., 2004a; Lewison et al.,2004b; Camiñas, 2004; Casale, 2008; Wallace et al., 2010). Casale (2011) compiled all available information for sea turtle by-catch in the Mediterranean Sea and estimated that small-scale fisheries may be responsible for up to 62,000 marine turtle captures/year in the region. Despite the fact that this number represents 40-45% of the total captures, the mortality rate is estimated at 26,500 individuals, a disproportionate 60% of the total estimated for the region (Casale, 2011). This can be mostly explained by the gear used by small-scale fishermen such as gill nets that include set nets, drift nets and trammel nets that cause high mortality rates (up to 70%) probably due to long soak durations (Casale, 2008; Snape et al., 2013).

Also of concern is the phenomenon of intentional killings occurring in Greece, Tunisia, Turkey and Egypt (Panagopoulou et al., 2007; Casale, 2008; Nada and Casale, 2011). Individual small-scale fishermen may only catch a few turtles and it may appear that these captures are insignificant; however the large size of the small-scale fleet suggests that overall cumulative by-catch could present a sizeable conservation challenge for sea turtles in the region (Soykan, 2008; Casale, 2011; Snape et al., 2013).

Greece has the largest small-scale fishing fleet in the Mediterranean. As of 2010, there were 15,832 registered vessels representing 88.2% of the total Greek fishing fleet (HMCR, 2010 census). A typical small scale fishing boat is between 6 and 12 m in length, with 1-2 people working on board and goes fishing an average of 209.2 days a year (13 – 20 days/month). Such boats are licensed to use more than one type of gear, the most common of which are gill nets, trammel nets (39.0%) and demersal long lines (34.4%). These types of gear and fishing techniques are interchanged depending on the season, targeting different species to obtain higher yields. Because of the smaller capacity and engine power, fishing grounds of these boats are generally close to the shore (Stergiou et al., 2002; Tzanatos, 2005; Ministry of Agriculture, Greece, 2007). Further, small-scale fishers are known to change ports and/or fishing refuges intra-annually, seeking to increase yields by changing fishing grounds.

Circumstantial clues such as numbers of turtles reported dead with evidence of capture in fishing gear (Kopsida et al., 2002, Panagopoulos et al., 2003), data derived from turtles admitted to ARCHELON's Sea Turtle Rescue Centre in Glyfada, Athens

(Panagopoulos et al., 2003; ARCHELON, unpublished data) and some anecdotal communications with fishermen (Karadaki and Panagopoulou 2006) suggest that the highest level of interactions and related mortality for loggerhead turtles in Greece is caused by small-scale fisheries (Margaritoulis et al., 2007; Panagopoulou et al., 2007; Casale 2008). In addition, small-scale fishermen in Greece have been reported to intentionally kill or injure sea turtles captured in their gear (Kopsida et al., 2002; Panagopoulou et al., 2007), therefore the mortality rates for this type of fishery may be far more serious than those of other fisheries and presents a conservation priority for Greek sea turtle populations.

Because of the characteristics of small-scale fishing activity, its impact on sea turtles and other marine megafauna is hard to quantify precisely. The small-scale fishing fleet is dynamic and the number of registered fishing vessels does not necessarily represent the number of active boats (Chuenpagdee, 2006). This is particularly true for Greece where the number of active vessels constantly changes as fishers receive subsidies from the EU to retire their boats (European Commisssion, 2008), or go into retirement. Small-scale fishing activity is flexible and dynamic, with fishers using a variety of fishing gear and techniques depending on the season, targeting a variety of fish species and operating throughout the year (Chuenpagdee, 1996; Moore et al., 2010; Chuenpagdee, 2012; Guyander et al., 2013). Observation programs are unfeasible to implement for logistical reasons (size and distribution of fleet, size of vessel, etc) (Moore et. al., 2010). Social science and survey research has increasingly been used as a way to cover this knowledge gap (e.g. Moore et al., 2010; Alfaro-Shigueto, 2012) and it has revealed important clues on the numbers of turtles caught in the Mediterranean Sea (Godley et al., 1998; Carreras et al., 2004; Battaglia et al., 2010; Quevedo et al., 2010; Snape et al., 2013).

To date, these studies have applied surveys and related research methods in an effort to quantify the extent of interactions between turtles and small-scale fisheries, focusing on the impact these interactions have on sea turtles. However, there are very few references in the literature as to how these interactions affect small-scale fishermen. Negative attitudes and opinions due to damages caused to nets and/or antagonism have been recorded for other species interacting with small-scale fisheries that include wetland birds in Vistonis lake, Greece (Daoutopoulos and Pyrovetsi, 1990), monk seals *Monachus monachus*) in Greece, grey seals *Halichoerus grypus* in Cornwall, UK (Glain and Kotomatas, 2001), cetaceans in the Mediterranean (Bearzi, 2002; Frantzis, 2007), otters *Lutra lutra* in Czech Republic aquatic ecosystems (Vaclavicova et al., 2010) and grey seals *Halichoerus grypus* in the Baltic sea (Varjopuro, 2011). Notably Godley et al. (1998) interviewed small-scale fishermen on the coasts of Turkey and northern Cyprus where the respondents reported that turtles impacted their livelihood by damaging their nets, spoiling their catch and removing bait, but there was limited analysis of these opinions or how the fishermen dealt with these issues. In many of these studies, the authors tried to quantify opinions and attitudes of the respondents, but did not manage to obtain qualitative data that would provide more in-depth insights highlighting hidden aspects of the problem.

A qualitative report based on discussions with fishermen compiled by ARCHELON the Sea Turtle Protection Society of Greece, revealed that sea turtles are perceived to cause damage to gill nets (set nets and/or trammel nets) and that this, combined with damage caused by other species such as cetaceans and monk seals, is one of the reasons behind the fishermen's hostile behavior and resulting retaliatory attacks (Koutsodendris, 2007). In that study some fishers viewed turtles as competitors because they consumed "their" fish or frequented "their" fishing grounds. The report was based on information collectively provided by several fishermen during group discussions, and not necessarily on robust scientific methods. However, its results support the existing literature suggesting that the issue of small-scale fisheries interactions with turtles is a complex, multi-faceted issue that appears to be connected to competition and antagonism directed towards more intensive fishing practices such as trawling (Glain and Kotomatas, 2001; Carreras et al., 2004; Chuenpagdee et al., 2006; Koutsodendris, 2007; Jacquet and Pauly, 2008; Chuenpagdee, 2012).

Rethymno on Crete is the third most important nesting area for loggerhead turtles in Greece and a site of regional importance for the Mediterranean. Because of its importance for sea turtle populations, it was included in the EU NATURA 2000 Network as a Site of Community importance (Directive 92/43/EEC). The site encompasses a marine area adjacent to Rethymno, up to the 50 m isobath. The designation of a protected area can be a powerful tool for the conservation of an important habitat for marine species, however it is only a first step. In many cases, MPAs have been met with scepticism and have even been rejected by some affected stakeholders (e.g. Halpern and Warner, 2003; Jentoft et al., 2012). In Rethymno, small-scale fishers are an important stakeholder in the area and, therefore, are likely to be affected by any management measures related to the Rethymno marine area. Therefore, investigating their perceptions, opinions and recommendations, before any management measures are designed and come into effect, is a key and seemingly necessary first step towards generating fishermen's participation and support in the successful implementation of management policies (Daoutopoulos and Pyrovetsi, 1990; Margravio et al., 1996; Marshall, 2007; Klein et al., 2008; Campbell and Cornwell, 2008; Hamann et al., 2010; Jentoft et al., 2012).

The purpose of this project was to survey local fishermen in Crete about their perceptions of fishing, and their interactions with sea turtles. In this study, I investigated fisher perceptions of the impact of sea turtles on them and their profession, their recommendations for possible solutions, as well as their views and opinions on protected areas. This is the first such study combining quantitative and qualitative data in order to provide a three-dimensional description of the impact of interactions between sea turtles and small-scale fishers, emphasizing the fisher's view point. Results from this study will be used to design and implement management policies for the marine section of the NATURA 2000 area. Because the issue of small-scale fisheries interactions is not a localized event, but rather a conservation challenge of regional importance, results of this research will be of benefit to other areas in the Greece and the rest of the Mediterranean.

Materials and Methods

I conducted a study to describe opinions and perceptions of small-scale fishermen on diverse aspects of their work including interactions with sea turtles and other species. I solicited these perceptions using semi-structured interviews. I used a questionnaire as the basis for these discussions. Interviews were conducted in Greek, and had a duration of between 40 and 60 minutes.

I selected Crete as an extended study area to reduce possible biases resulting from a multi-year co-existence between the Rethymno fishing community and ARCHELON, the Sea Turtle Protection Society of Greece. Another advantage in selecting Crete as a study location was the heterogeneity in the distribution of fisheries. Small-scale fishing ports and refuges exist within larger towns and cities (e.g Chania, Rethymno, Heraklion, Agios Nikolaos, Ierapetra and Siteia) as well as in smaller, more isolated villages (e.g. Palaiohora, Hora Sfakion, Georgioupolis, Agia Galini, Cherssonissos, Kokkinos Pyrgos, Elounda, Tsoutsouras, Paliakastro, Makrygialos). These ports are geographically distributed along both the northern and the southern coasts (Figure 4.1).

The most common way to encounter fishermen was by visiting fishing ports, because fishers tend to spend several hours each day at their fishing vessel preparing their catch for the market, grooming their gear or carrying out other maintenance tasks (e.g. Carreras et al., 2004; Moore et al., 2010; Nada and Casale, 2011; Alfaro-Shigueto, 2012). Between June and August 2013, I visited 18 fishing ports distributed around Crete in order to record the perceptions and opinions among small-scale fishers. I asked about sea turtles and the impact that they and other large marine vertebrates had on fishers and their livelihood. I also asked about the top challenges they faced in their profession, and about their views on marine protected areas (MPAs).

For each port I visited, I first identified and made contact with the local opinion leader before approaching any of the other fishers in the area. Fishermen working at a particular port or a municipality usually form a local Fishermen’s Association, whose main role is to promote their interests and to act as a liaison between their members and the local authorities. The Presidents of the local Fishermen’s Associations as well as older fishermen, can be viewed as “gatekeepers”; they are seen by the other active fishermen as “father figures” or mentors, and their opinions are likely to influence their local colleagues. Therefore, connecting with and securing endorsement from these figures helped me establish a better rapport with the local fishermen and increased their willingness to participate in my study (Broadhead and Rist, 1976; Campbell et al., 2006).

After talking to the local opinion leader, I proceeded with interviewing other fishers, typically approaching the boat skipper/owner first. I provided a brief overview of my project, and asked the fisher if they would like to participate. I sought to interview respondents on a one-on-one basis so as to reduce biases associated with peer presence. This was not always possible, however if they agreed, I asked for verbal consent, assured them of confidentiality of responses and made it explicitly clear that they could interrupt the interview and/or ask questions and stop at any time. To maintain anonymity, I allocated an alphanumerical code to each respondent. Each interview took between 40 and 60 min to complete, depending on the length of the responses provided.

The best time to talk to the fishers was later in the day after they had returned from their fishing grounds and were in the process of selling their fish or grooming their gear. This allowed me to conduct interviews without directly interfering with or disrupting the fisher’s work, thus avoiding potential irritations that would make them less willing to participate, especially given the relatively long duration of the interview (Silver and Campbell, 2005). Therefore, almost all interviews occurred at fishing ports, usually on the boat or on the dock as the fishers were selling their fish.

The survey design and data collection

I opted to use a questionnaire as the basis for my semi-structured interviews, because I needed structure and consistency to help ensure comparability of results. At the same time, I wanted to be flexible and incorporate comments volunteered by the participants. The questionnaire included a combination of open-ended and closed-ended questions about the fisherman and their catch, incidents of captures with non-target species, their opinions on challenges to their profession, and their views on Marine Protected Areas (MPAs). The questionnaire had 36 questions and was split into four sections: Demographics (Part I, Questions 1 - 8), Fishing Activity and observed changes in the catch (Part II, Questions 9 - 18), interactions with turtles and other species (Part III, 19 - 30) and fisheries management issues (Part IV, 31 - 36) (Appendix A). When designing the questionnaire, I constructed it with strategic question types and pairings, to facilitate triangulation and to reduce purposeful false reporting. (Silver and Campbell, 2005). Further, I designed the questionnaire in a manner that was as neutral as possible, focussing on the fisher perceptions and opinions rather than emphasizing the welfare of sea turtles and other large marine megafauna.

I also adopted a strategy of using different query techniques to obtain similar information in different sections of the questionnaire. Further, I used a combination of open-ended (qualitative) and closed-ended (quantitative) questions, including Likert-scale and rating scale type questions and simple yes/no answers (Oppenheim, 1992; Babbie, 2009). This allowed me to test consistency of responses by triangulating (Olsen, 2004). To reduce social desirability biases and to avoid fishers implicating themselves, in questions touching upon sensitive issues, I provided statements where they were required to rate the degree of importance or state their level of agreement (Fisher, 1993; Grimm, 2010). To construct these statements, I drew on responses fishermen suggested elsewhere (e.g. Koutsodendris, 2007), previous research on small-scale fishermen in Greece and the Mediterranean (Daoutopoulos and Pyrovetsi, 1990; Glain and Kotomatas, 2001; Carreras 2004; Nada and Casale, 2011), and fisher's opinions, and perceptions on conservation and fisheries management issues (e.g. Daoutopoulos and Pyrovetsi, 1990; Glain and Kotomatas, 2001; Silver and Campbell, 2005; Hamilton, 2012; Leleu et.al., 2012). Before collecting formalized data, I piloted the questionnaire by conducting "mock" interviews with 8 professional and recreational fishers operating in Rethymno. I checked for clarity of questions, errors and the presence of potentially polarizing queries that might deter respondents from participating.

There were a total of 819 fishing vessels registered on one of the four central Coast Guard Stations of Crete (From West to East: Chania = 345, Rethymno = 82, Heraklion = 191, Lasithi = 201) (HCMR, 2010 census). Small-scale fishermen may have been based on any of the fishing ports or fishing refuges around the island regardless the site of registration. At the time my field research was conducted, it was highly unlikely that all 819 vessels were still active. Several boats had been decommissioned since the 2010 census, as their owners retired or participated in national and European Union programs providing incentives to reduce the fishing effort through decreasing the size of the fishing fleet (Greek ministry of agriculture, 2007; European Union, 2008). The list also included vessels that were licensed to fish but were inactive. These factors presented sampling constraints both in terms of determining sample size and selecting a probability sampling method (e.g. Oppenheim, 1992; Kelley et al., 2002; Moore et. al., 2010; Bernard, 2012).

To offset these disadvantages, I used a combination of convenience and snowball sampling (Oppenheim, 1992; Kelley, 2002; Babbie, 2009). Snowball sampling was applied when some of the respondents or the “gatekeepers” recommended me to other potential respondents. This method was advantageous in that it worked via recommendations from one fisherman to the next. This seemed to increase my credibility, and may have been a factor in establishing rapport, generating trust and increasing willingness to participate in the survey (Glain and Kotomatas, 2001). Convenience sampling was applied when I approached fishers who were present when I visited their port. I also applied convenience sampling usually during subsequent visits at the same port. I restricted interviews to one person per fishing vessel (Himes, 2003; Carreras et al., 2004).

Data analyses

Responses to demographics and closed-ended questions are presented as summary statistics. I did not attempt to establish statistical relationships between respondent characteristics and responses provided. I was primarily interested in identifying general patterns and presenting an overview of small-scale fisher perceptions and opinions as a whole.

To analyse responses to open-ended questions, I used adapted grounded theory (Strauss and Corbin, 1994; Charmaz, 2006). Grounded theory usually starts with the collection of data, which are then coded and grouped into themes and concepts from which categories are formed. These categories are used to create a theory, or a "reverse engineered hypothesis" (Charmaz, 2006). I coded responses to open-ended questions, as well as any additional comments provided by the respondents, by grouping responses into themes. A theme was determined when 10 or more respondents provided answers or comments similar in nature. For example, "invasive species" emerged as a theme when a significant proportion of the respondents stated that this was one of the major changes observed in their catch. I refined initial codes and themes as analyses of data progressed and new insights appeared. For example, "invasive species" was refined into "pufferfish (*Lagocephalus sceleratus*)" as it became apparent that this was a topic of major concern for many of the respondents. Themes were grouped into categories derived from the data. I conducted all coding process using QSR-NVivo 10 software designed to assist with qualitative data analyses.

The study and questionnaire were also approved by Drexel University's Institutional Review Board ("Small-Scale Fisheries and Sea Turtles on Crete, Greece") as is required of research with human subjects.

Results

Between June and August 2013, I visited 18 ports around Crete, spoke with 111 professional fishers, and conducted a total of 101 in-person interviews. Therefore I interviewed approximately 1 member from 12.3% of the total registered small-scale fishing fleet for the island. Of the 10 fishers who declined participating in the study, 4 gave no reason for their refusal. The other 6 did so because they "were not in the right frame of mind” (n = 3) or felt that this study was not going to help with anything (n = 3), as illustrated in the comment provided by one of them:

“You came too late – there is no point in doing this.”

All participants were male, usually older than 45 years of age, and had been fishing professionally for 30 years on average. Fishing was generally self-reported as the primary source of household income (Table 4.1). Their fishing vessel was typically less than 10 m long (average = 8.6 m), of low engine power, and licenced for diverse gear that include gillnets (set nets, trammel nets) and demersal long-lines. Their fishing grounds were within 6 n.m from the shore and they had a limited distribution network for their catch (Table 4.2).

The majority of fishers who took part in the survey were 45 years of age or older (72%) and only 9% were younger than 35. This was likely reflective of a lack of recruitment of young people to the profession, which was commented upon by some of the respondents, usually to support the general idea that there was no future in small-scale fishing:

“…no young people become professional fishermen.” (A10)

“There are no young fishermen” (K02)

“For young fishermen it is unsustainable to become a professional fisher.” (J02)

“It is not possible for a young person to work at sea [as a fisherman].”(CD12)

“I wanted to get my own son into fishing, but now I am telling him to go be a waiter.” (I10)

Fishing activity and reported changes in catch

All fishers who had been active for more than 5 years (n = 98) reported changes in their catch. A major change noted by the fishers (54%; n = 98) was the appearance of alien species that had entered the Mediterranean from the Red Sea through the Suez Canal and established populations (Lessepsian migration) (Stergiou et al., 2011). Two of these species, the dusky spinefoot (*Siganus luridus)* and the pufferfish (*Lagocephalus sceleratus),* were considered by fishers to be highly undesirable. *Siganus luridus* was a small fish (average length = 14 cm), but it was captured in large quantities, was difficult to remove from the net and although edible, was unpopular with consumers. Further, respondents believed this fish to be territorial, displacing other fish species. Pufferfish can grow to a length of 110 cm, and weigh up to 7 kg. This fish is extremely poisonous, its tissues containing the lethal neurotoxin tetrodoxin (TTX) and its sale and consumption are banned within the EU (Stergiou et al., 2011). Pufferfish were reported to cause great damage to fishers gear on a daily basis. In addition, 19% of respondents implicated pufferfish as having the highest impact on their catch because they were alleged to have eliminated all cephalopods from the area. For these reasons, respondents considered pufferfish as a pest in need of extermination, and called on the government to set up culling campaigns:

> *"Pufferfish are like the Pharaoh's plagues – they bring in no income and cause damages" (K10)*
>
> *"The government should give subsidies to fishers to fish them out" (I01 – I12, Ia01 – Ia03, J01 – J09)*

It is interesting to note that 12% of the interviewed fishers believed that the appearance of invasive species was a result of climate change and warming sea water temperature:

> *"Increase of temperatures – we get the climate/sea conditions Libya used to have; The Ionian Sea now has the climate/sea conditions Crete used to have. So fish we used to have here have moved there. We have an increase in number of species because of invasive species such as the dusky spinefoot that have come through the Suez Canal" (A01)*
>
> *"The sea water temperature has changed and creates a problem because new fish move in here" (H01)*
>
> *"[The environment] has only been affected by the temperature, there are new species appearing here and other fish that used to be here have moved on." (I09)*

Nearly all respondents (98%) stated that their catch had decreased up to 90% over the last 5 – 10 years. Further, 97% believed that there was a general decline in fish abundance. Respondents also reported declines both in terms of the size of fish (79%) and the number of species caught (60%; n = 98) (Figure 4.2). Some fishers elaborated that many of the high-value fish like groupers (*Epinephelus aeneus, Epinephelus fasciatus, Epinephelus marginalis*), dentexes (*Dentex dentex*, *Dentex macrophthalmus*), and lobsters (*Palinurus elephas, Scyllarides latus*) had all but disappeared:

> *"Common Pandora, red mullet, striped mullet have disappeared from the area. Where are the 6 and 7 kg common dentexes? Where are the 1.5 and 2 kg lobsters?" (CD07)*
>
> *"We do not catch commercially high valued fish like lobsters, red mullets, white sea breams, common dentexes, lobsters and other prime category fish" (E06)*
>
> *"Prime fish species are greatly reduced. There is overabundance in bogues and round sardinellas, but mullets, sea breams and grouper species are greatly reduced in number" (K10)*

Many of the respondents (55%; n = 101) perceived trawling activity as responsible for depleted fish stocks (Figure 4.3). They commented that bottom trawlers indiscriminately captured fish before they had the chance to breed, destroyed benthic habitats that served as refuges for juvenile fish and illegally hauled their gear too close to the shore:

> *"They discard 80% of what they catch, they catch very small fish and destroy the sea bed." (A04)*
>
> *"They damage the sea bottom, they work during April and May when the fish are pregnant with eggs, so they never breed" (B04)*
>
> *"They do not abide by the law – they kill all the juvenile fish when they enter shallow waters." (CD06)*
>
> *"Whoever allowed trawlers to fish in April and May destroyed our children's future. It is no good if all the juvenile fish are destroyed by the trawlers." (L09)*

Several respondents (37%; n = 101) reported non-professional fishers who possessed recreational fishing licenses and/or went spear-gun fishing as having the highest impact on their catch. Respondents viewed these fishers as using fishing gear in excess of what they were allowed, as having the ability to use better boats with stronger engine power and/or purchasing better and more expensive bait. All these factors were suggested as reasons for better catches than the professional ones. Spear-gun fishers were also discussed as selectively going after the large fish of high commercial value (e.g. groupers) and as engaging in illegal fishing practices such as using scuba equipment or night fishing using floodlights.

Non-professional fishers were also believed to undercut prices by selling their catch to shops and restaurants illegally:

> *"They work with professional gear and illegally sell their catch. Same with spear gun fishermen. They undercut the prices of fish because they are willing to sell at cheaper rates." (CD03)*
>
> *"Spear-gun fishermen have caught all the dusky groupers. There is gear specializing in catching large-eye dentexes available to non-professional fishers. They catch very small fish." (E06)*
>
> *"Amateurs using scuba equipment get to deep waters, catch all the big fish and they sell them illegally." (I01)*
>
> *"…they have become more professional than professional fishermen themselves. They use more sophisticated tools, they use better bait and they take over." (J01)*

Some respondents (19%; n = 101) identified increased fishing effort as a whole as having the greatest impact on their catch, suggesting that several factors cumulatively contributed to the depleted fish stocks. Further, several fishers (22%) admitted that they also were also partly responsible for the depletion of fish populations:

> *"We are poking our own eyes out. I take my nets, then let them soak for a week. We catch undersized lobsters and juvenile fish and we keep them." (CD12)*
>
> *"First we should fix our own back yard. Fishing gear should not be allowed to soak for a long time." (A07)*
>
> *"We have also contributed to reduced numbers of fish. We use too many nets and we overfish." (A05)*
>
> *"Small-scale fishermen also do harm; we use 18 mm mesh size nets and we let them soak overnight." (K06)*

All of the respondents (n = 101) stated that these changes brought great financial strain to them. They were suffering losses of income, while their operating costs were increasing:

"I can barely get by." (A02)

"I am financially ruined. I am up to my eyes in debt." (A11)

"I catch fewer fish. I work day and night and I barely make 30€." (H03)

"I work more, have more damages and I cannot earn my daily living." (K04)

To maintain their income and to compensate for reduced catches, 74% (n = 101) of the fishers said that they had increased their fishing effort, recognizing that this may have aggravated the problem of depleted fish stocks. The increased fishing effort was indicated by an increase in the amount of gear used (61%), an increase in the amount of time invested in fishing and the resulting increase in fuel expenses and other operating costs (41%), having to travel further to fish (15%) and/or reducing the size of gear to catch smaller fish (6%):

"We go after whatever is left and whatever we can catch" (G01)

"We use more gear and contribute to overfishing ourselves" (F02)

"When my income is reduced I am forced into increasing my gear. I do more harm, but there is nothing else to be done" (Ia01)

"I use 3-4 times as many gear and I still cannot make a living. I go further to fish" (Ia02)

In short, many fishers (45%) summarized their plight as having to work harder, facing increased operating costs and all the while, catching fewer fish:

"More work, more gear, more effort for less money" (K08)

"More effort, fewer fish" (L04)

"More gear, more bait, more expenses" (I05)

Interactions with turtles and other species

Nearly all respondents (95%; n = 101) stated that they interacted with sea turtles, usually without the animal getting captured in gear. They also indicated interactions with other marine megafauna like monk seals (98%), dolphins (97%), large fish such as elasmobranchs and amberjacks (*Seriola dumerili*) (24%), as well as the invasive pufferfish (59%) and sea birds (7%) (Figure 4.4).

Many of the respondents (77%, n = 101) admitted that turtles were occasionally caught in their gear, but only 40% indicated captures during the 12 months prior to the interview, and those occurred mostly in gillnets. I did not probe for further information on these captures (species, location, depth, time of year, fate of the animal etc.) because I did not want to draw the focus away from the fishers and the impacts that those incidents had on their fishing activity and livelihoods. Respondents affirmed that all encounters with sea turtles resulted in damage to fishing gear. Some fishers (28%; n = 101) reported that the turtle ate the fish they had caught. In 21% of cases this was not perceived as a big problem, with the respondents considering this behavior to be "natural" and possibly attributable to other factors like lack of food sources:

"They will just eat a couple of fish" (B02, F01)

"I disagree with those who dislike turtles because they eat fish. What else are they supposed to eat? Steaks?" (L09)

"When fish numbers are decreased, the animals go crazy and they go after the easy solution" (G01)

"We are suffering damages from animals that do not find anything else to eat" (E01)

Others viewed this as a problem causing loss of income for them:

"They eat my production" (L12)

"I dislike them – they take my bread away from me" (I05)

"They ate my fish" (I12)

"They will keep eating fish until they get caught" (A11)

Interactions of turtles with demersal longlines were not reported as resulting in significant financial losses because respondents did not consider damaged longlines and loss of hooks to be costly. However, they remarked that they did lose income because of sea turtles rendering their gear ineffective:

"[The turtle] pulled the longline at the surface and it did not fish" (K01)

Respondents attributed observed gear damages to certain species depending on the nature of the damage. They stated that sea turtles left distinctive marks on gillnets. These were described as 1 – 5 holes (51%) and small rips (21%) created as turtles try to pull fish away from the net using their beak and flippers. Turtles were also said to leave fish remains chewed to a pulp on the net, causing clumps which were hard to remove (33%). Respondents also stated that their nets got completely destroyed when they encountered dolphins because they ripped them to shreds eating all the caught fish. Monk seals created big holes in the nets according to respondents. Thus, each species was associated with distinctive gear damage and depredation “calling cards”.

I attempted to estimate the financial impact resulting from interactions with sea turtles by asking fishers to comment on estimated cost of damages, and the amount of time spent fixing gear during the 12 months prior to the interview. Some respondents stated there was no associated financial cost (7%), that it was negligible (11%) or that was less than 100 € (4%). These respondents predominantly used demersal long lines or said that sea turtles were responsible for only a small fraction of the total damages they encountered. Damage to gillnets was reported as more costly: 36% of respondents stated that they spent between 100 and 1000 € to replace damaged gear, and another 18% indicated costs ranging between 1,000 and 2,000 € during the 12 months prior to the survey (n = 101). An additional 20% said they had spent sums in excess of 2,000€ (Figure 4.5). Some respondents (34%) stated that they spent no time fixing gear damaged by turtles claiming it was unfixable, while others (46%) said they had dedicated up to 60 working days mending gear in the 12 months prior to the interview. This dichotomy may be explained by the fact that in areas where interactions are more frequent, fishers may spend more time fixing gear in an effort to reduce costs related with replacing it. Others consider mending and assembling gear an integral part of their job:

> *“Fishermen dedicate 360 workdays [to their job]. When they are not out fishing, they sew and mend their nets or prepare new sets of nets.” (L08)*

Some fishers (21%) perceived sea turtles as blameless because the sea is their natural habitat:

> "*It is us who steal [the turtle's] food. If we get this, we will become better fishers." (B03)*
>
> *"Some fishers view turtles as competitors. There is no reason for that. We are the ones interfering with their home." (H01)*
>
> *"If an animal has been sent by God, there is a reason for it to be around and to exist at sea. It is part of the ecosystem." (L09)*
>
> *"Marine animals were here before we were." (L10)*

A few of the respondents expressed appreciation for sea turtles, but stated that they considered them a problem for their fishing activity:

> *"As a human being, I do not hate them. As a professional fisher, I have a big problem with them." (L11)*
>
> *"Sea turtles are a problem. (…) I disagree with relocating turtles. My children should be able to see them. I want the turtles here." (A11)*

Of all respondents who had been active for more than 5 years (n = 98), the majority (69%) suggested that sea turtles had been increasing in the last 5 – 10 years. Others stated that sea turtle populations were decreasing (12%) or remained the same (14%). Some fishers indicated sea turtles and their perceived increase in numbers as problematic to them and their fishing activity, suggesting that their populations should be moderated or eliminated:

> *"I think that turtles are a big threat to the local fishery because there are too many of them here (…) Things should go back to the way they were before when people used to eat them." (A07)*

> *"We do not need so many turtles here. They dumped 500 on Zakynthos and they have spread everywhere." (CD01)*

> *"Sea turtles should be restricted." (CD03)*

On the whole, respondents did not name sea turtles as the "worst offender"; only 8% stated that sea turtles caused the greatest amount of damages. Most respondents (49%) viewed dolphins as the leading species in terms of damages, followed by the invasive pufferfish (22%) and monk seals (19%) (Figure 4.6). Nearly three quarters of the respondents described sea turtles as interfering with their fishing activity a little bit (55%) or not at all (19%) and that said that they posed a limited (52%) or no (22%) threat to the local fishery. Cumulatively, however, the combined impact of interactions with sea turtles, dolphins and seals was seen as one of the top three challenges for the local fishery, listed as such by 59% of respondents (Figure 4.7). Some fishers expressed their frustration and desperation over damages caused by dolphins, seals and sea turtles, and the lack of related provision on the part of the government:

> *"Sea turtles, seals dolphins, they are all together the same thing. There is a lot of promotion among the public about sea turtles and their protection. And who will protect us?" (CD04)*

> *"1,500 yards of brand new nets and they have ripped them to shreds – how am I supposed to like them?" (CD06)*

> *"I almost went mad from the many damages I had." (L05)*

> *"Sometimes you feel like crying when you see the damages caused by the animals on your gear." (A04)*

Of the respondents who listed interactions with dolphins, seals and sea turtles as one of the top challenges faced by the local fishery (n = 59), the vast majority (83%)

recommended that the government should provide compensation to offset costs of gear damaged as a result of these interactions. A sample quote indicative of this stated:

> *"We cannot avoid or get past [these animals]. So they [the government] should compensate us." (F07)*

According to respondents, this compensation could be in the form of subsidies for gear replacement, tax deductions, annual stipends or gear supplied directly by the government. Some respondents (n = 9) suggested compensation as indispensable in terms of preventing intentional killings of animals seen as threats:

> *"Yes, my colleagues kill turtles. They receive no compensations from anywhere. At this rate none of my colleagues will let the turtles go – they will kill all of them." (L12)*
>
> *"If I find a turtle I will kill it, since we get no compensations. We are ruined. I have no money to mend my nets (…) Give incentives to the fishers so they can respect these animals." (Ia02)*
>
> *"Unless the government provides compensations, fishers will continue to kill turtles." (A04)*
>
> *"If they [the government] give compensations to fishers, they will take more care of [the turtles]." (A11)*

Interestingly, some fishers (n = 6) proposed measures to restore fish stocks as the best way to alleviate impact of interactions with large marine vertebrates:

> *"Restore fish populations so that [the animals] do not come to our nets." (F03)*
>
> *"If the sea was adequately protected, there would be no need to provide compensations." (A03)*

A third of respondents (31%) supported the idea of removing the turtles from the area and relocating them to other protected areas. The majority (63%) were opposed, partly because they did not consider such a measure to be feasible (30%). Similar responses were provided about dolphins and seals: while 38% of the fishers would like to have them removed, 58% were opposed to the statement partly because of its unfeasibility (28%).

Views on Marine Protected Areas (MPAs)

The majority of the fishers (76%) who participated in the survey were in support of the government establishing MPAs and/or areas closed-off to fishing. An even larger proportion of respondents (87%) were in favor of establishing fishing refuges. However, stated perceptions of MPAs were more complex than it originally appeared (Figure 4.8). Some fishers (n = 17) expressed doubts over whether such areas would be properly implemented, believing that they would be poorly enforced and supervised:

> *"Even if there is a restriction, people will still go to fish there." (Ia01)*
>
> *"…areas closed off to fishing: no-one with obey this regulation" (F02)*
>
> *"I agree with establishing area completely closed off to fishing, but how would this be enforced?" (CD02).*

Of the respondents that provided additional comments (n = 71), 49 expressed favorable views of MPAs. Some (n = 16) stated that the establishment of MPAs would be good for the fish all the while recognizing that MPAs could result in them losing fishing grounds:

> *"[MPAs] would be good for the fish, bad for us" (A11)*
>
> *"I agree with the establishment of protected areas, although it is not to our advantage" (L01)*

"It will be good for the fish" (A11, K04)

In addition, while some of the respondents (n=27) suggested MPAs as a good management tool, they included comments about MPAs only succeeding if implemented under certain conditions. A few fishers did not further explain what they meant by "conditions". However, 20 of the respondents stated that proposed MPAs or areas closed off to fishing should not be permanent and that the core protected areas should be flexible and change over time or be combined with additional measures to restore fish populations:

"Areas should be closed off to fishing for two years at a time, interchangeably and they should create artificial reefs." (L13)

"I strongly agree with the establishment of fish refuges in some areas allowing fishing in others. But this should be done interchangeably."(J01)

"I agree with the establishment of fishing reguges/marine protected areas, but this should not be a permanent measure. They should have a set of areas where this is interchangeably implemented." (I05)

"There should be areas closed off to fishing periodically, so they have time to recover." (H01)

"They should let the sea rest from fishing. They should close areas off from fishing, interchanging them every five years." (E03)

In addition, several respondents (n = 6) stated that they would be supportive of MPAs, but that it was necessary that they be compensated for the loss of income resulting from the restrictions on their fishing activity:

"I think that closing areas off to fishing is beneficial, but fishermen must be compensated for not fishing." (A04)

"If they are to establish protected areas because of turtles they must compensate me" (G01)

> *"The creation of Marine Protected Areas has a very positive impact on the catch. It is needed, but the local professionals need to be provided for." (L11)*

The general idea that the establishment of MPAs or areas closed-off to fishing will result in further restrictions on small-scale fishers was also provided as the main reason for being opposed to them (n = 15):

> *"I disagree with the idea of Marine Protected Areas/Fishing refuges, because this is not feasible for here. We have two reefs in the area, if fishing is restricted there, where are we to go?" (A03)*
>
> *"I strongly disagree with the idea of establishing areas closed off to fishing – where will the fisherman go?" (B01)*
>
> *"If they are to close areas off to fishing, make protected areas or increase regulations, where will the fisherman go?" (CD05)*

Discussion

My findings provided valuable insights into the views and perceptions of fishers working in Crete. Respondents commented on interactions with sea turtles and other marine species, the potential for Marine Protected Areas, and challenges in their profession. Over the course of this study, I was able to collect a combination of quantitative and qualitative data, which helped to offer a general portrayal of the respondents' opinions and perceptions. The qualitative data provided through replies to open-ended questions and additional comments by respondents enriched the data and allowed for informed interpretation of the quantitative data, providing a more comprehensive description of small-scale fisher views and opinions.

Demographics

Respondent characteristics were similar to those previously reported for small-scale fisheries in Greece (Tzanatos, 2005; Tzanatos et al., 2006; Ministry of Agriculture, Greece, 2007; Gonzalvo et al., 2014), and worldwide (Chuenpagdee, 2006; Chuenpagdee, 2012; Silva et al., 2015). This suggests that despite the limitations of non-random sampling methods used in this study, its demographic results were in line with other studies of Greek small-scale fisheries.

Sea turtles caught in small-scale fishing gear

Nearly all fishers who participated in this study stated that they interacted with sea turtles and that these encounters resulted in damages to their gear, albeit minor in some cases. Respondents stated that they did not capture sea turtles very frequently, with only 40% of them reporting turtles caught during the 12 months prior to the survey. When I estimated the reported captures over the 12 months prior to the interview, I found that between 111 and 123 captures likely occurred during that period. The fate of these animals was unknown, but in a hypothetical scenario with captures in gillnets having a direct mortality rate of 60% (Snape et al., 2013), these captures may have resulted in 66 – 74 deaths. Although there are no data to corroborate this conclusion, I argue that while turtle captures may appear insignificant if viewed from a single fisher's perspective, they may compose alarming levels if considered cumulatively, especially if we take into account the size of the Greek small-scale fishing fleet. I therefore suggest that interactions between sea turtles and small-scale fishers remains a key conservation challenge for sea turtles that should urgently be addressed, as concluded in other studies in Greece (Gonzalvo et al., 2014), the Mediterranean (Carreras et al., 2004; Battaglia et al., 2010; Quevedo et al., 2010; Snape et al., 2013) and worldwide (Peckham et al., 2007; Alfaro-Shiguetto et al., 2011; Alfaro-Shigueto, 2012).

Declining fish stocks as an underlying cause of increasing interactions with sea turtles

During my study, it became clear that small-scale fishers in Crete faced many challenges to their profession, the most important of which was declining fish stocks. Respondents almost unanimously reported observing severe declines in numbers of fish caught, and in fish populations in general over the last 5 – 10 years. They also described the financial strain they were experiencing as a result. These declines were attributed to competitive fisheries (middle range fisheries; non-professional fishers; increased fishing effort in general) and to environmental factors (climate change; invasive species; sea turtles, dolphins and seals; marine pollution).

Small-scale fishers also observed similar declines in Western Greece, stating that they first noticed them during the 1990s (Amvrakikos Bay, W. Greece) or after 2000 (Ionian Archipelago) (Gonzalvo et al., 2014). Declining fish stocks have also been reported by small-scale fishers working in the Aegean Sea (Glain and Kotomatas, 2001). The perception of declining fish stocks is consistent with relevant studies documenting overexploitation of fish stocks in Greece, noting declines that first appeared during the 1990s after several decades of continuously increasing catches (e.g. Stergiou and

Koulouris 2000; Stergiou et al., 2011; Moutopoulos and Stergiou, 2012; Moutopoulos et al., 2015), as well as the rest of the Mediterranean (e.g. Sala, 2004; Coll et al., 2010).

These declines are the cause of significant financial strain for the fishers whose mean annual income in 2006 was reported at 10,451 € (Tzanatos et al., 2006). Small-scale fishers are highly dependent upon fisheries resources. They have few options to improve their efficiency by modernizing their fishing vessel and their gear or altering their fishing activities, like going further off-shore to fish. Such improvements also bring increased costs, which rather than improving their well-being, can push them further into “a vicious circle of poverty” (Chuenpagdee, 2012: 27). This is illustrated in the case of fishers working in Crete: to compensate for declines in their catch, 74% of the respondents stated that they increased their fishing effort by increasing the amount of gear used, travelling further to fish and/or working longer hours. This in turn increased their operating costs (fuel, maintenance, etc.), with no real financial gain.

Increased efforts and associated costs were not the only concerning response. In Section III of the interview, 69% of the respondents stated that they believed sea turtles were increasing in the area. The perception of an increasing population however, was not consistent with data from the major nesting beaches on the island, which indicated sharp declines in the numbers of clutches deposited each season (Margaritoulis et al., 2008; 2009; Margaritoulis and Panagopoulou 2010). Rather, it is possible that as fishers intensified their effort and invested more time into fishing, the probability of them encountering sea turtles also increased. The resulting increased number of encounters may have given the false impression that sea turtle populations on Crete were on the increase. In fact, sea turtles, although decreasing in numbers, could have been interacting much more frequently with the fishers. As a result, the adverse effects of these interactions could be responsible for high mortality rates (Casale, 2011; Snape et al., 2013), which may be one of the underlying reasons behind the sharp increase in the numbers of sea turtles reported dead in Greece (Margaritoulis, pers. communication).

Further, these interactions came with an associated costs for the fishers. Of the fishers interviewed, most (54%) reported that encounters with sea turtles during the 12 months prior to the interview resulted in losses ranging between 100 € and 2,000 €, with most accounts being in the range of 500 € - 2,000 € (n = 33). Given the low income generated through fishing (Tzanatos et al., 2006), this amount may take away a significant portion of the revenue and significantly impact fisher earnings. Combined with increased operating costs, this is additive to already dire circumstances for fishers and will likely heighten the animosity or apathy towards sea turtles. Therefore, a perceived increase in numbers of sea turtles may lead to more retaliatory attacks. This was hinted at by several of the respondents who participated in this study:

> *"The more these animals are protected, the worse the situation will get" (F02)*
>
> *"If sea turtles increase more, they will start killing them" (E02)*
>
> *"We should not let turtles become too many" (A06)*

These findings suggest that interactions between sea turtles and small-scale fishers are highly dynamic relationships and are likely to change in response to external factors such as the perceived state of fish stocks and/or fisher-turtle interactions.

Interactions with sea turtles should be viewed as part of a set of larger problems

Respondents stated that sea turtles were not the only species that caused damage to their gear. They also reported interacting with other species of marine megafauna including dolphins, monk seals and large fish such as dogfish and amberjacks. Fishers claimed to be suffering extensive damages caused by the invasive pufferfish *Lagocephalus sceleratus.* These were reported as occurring on a daily basis and in some areas were listed as the #1 problem for small-scale fishers:

> *"[Pufferfish] cause more damages than all the [other animals] put together." (I03)*
>
> *"Pufferfish is the leader of all [that which impacts my catch]." (I09)*

Notably three quarters of the fishers who participated in the survey considered sea turtles as only interfering with their fishing activity a little bit or not at all and said that they posed a small or no threat to the local fishery in general. Dolphins, followed by pufferfish and monk seals were thought to cause the greatest amounts of damage to fishing gear. Only 8% of respondents thought that sea turtles were responsible for the greatest destruction. These findings are in part consistent with similar studies undertaken in Greece and the Mediterranean. For example, fishers in Alonissos (Sporades Islands), where the largest remaining monk seal *Monachus monachus* population resides, state that most damage to gear is caused by dolphins and sea turtles (Glain and Kotomatas, 2001). Fishers working in Amvrakikos Bay (Western Greece) state that sea turtles residing there are causing much more damage than dolphins, while in the Ionian Archipelago, it is seals that are named as the "worst offenders" (Gonzalvo et al., 2014). In Turkey, dolphins and seals are thought to have the highest impact on gear, while in Cyprus, local fishers view sea turtles as having the highest impact (Godley et al., 1998).

The results from those other regional studies raise the possibility that my findings may be at least in part influenced by “interviewer effect”, where respondents consciously or subconsciously provide answers they think the interviewer wants to hear (Davis et al., 2010). On the other hand, there are other factors to consider, and fisher responses should be interpreted in context of the area and the ecology of the species. For example, Crete is one of the largest islands in the Mediterranean, with a relatively narrow continental shelf, and sea turtles are locally present during their reproductive season (April – August), at the end of which most of them depart for their distant overwintering sites. During their reproductive period, sea turtles are known to fast and opportunistically forage only if food is available (Hochscheid, 1999; Tucker and Read, 2001; Schofield et al., 2007; Fossette et al., 2008). Amvrakikos Bay is a shallow, semi-closed bay with only a narrow channel providing communication with the Ionian Sea, and it was recently identified as a foraging area for sea turtles (Rees et al., 2013). As a result, it may be possible that sea turtles are causing more damage to fishing gear in that area because they are actively feeding while residing in the Bay, whereas they only may occasionally do so while present in the waters off Crete. This might account for the perception that they cause less damage than dolphins and seals as reported by the fishers of Crete.

Analyses of results indicated that fishers spoke of interactions with sea turtles as a cumulative problem, and one that should be considered in conjunction with interactions with dolphins and seals. These animals combined were implicated as one of the top three challenges faced by the local fishery by 54% of the respondents, and similar results exist in other studies (Godley et al., 1998; Glain and Kotomatas, 2001; Gonzalvo et al., 2014). Further, reported costs associated with sea turtle gear damage in the 12 months prior to the survey were for the most part given as a percentage of the total amounts spent replacing gear destroyed by dolphins, seals and sea turtles. This suggests that sea turtle related damage is conceptualized as part of a larger problem that could be labelled as "animals interfering with gear". This was also reflected in the way respondents referred to dolphins, seals and sea turtles: many fishers (24%) used a single term when discussing damages to gear, whether it was "the beasts", "the animals", "the spirits" or "miara" (which in local dialect means the "unholy ones"). Therefore, a more holistic approach is needed and management decisions should take into account interactions with all species of marine megafauna rather than focusing on a single species like sea turtles.

Compensation is a good first management measure

Most respondents (83%) indicated that the best solution to alleviate the negative impact of interactions with sea turtles, dolphins and seals is for the government to provide compensation for their damaged gear. Compensation was also recommended as a solution by fishermen in Alonissos (Glain and Kotomatas, 2001), indicating that this opinion might be shared by fishers across the country. Compensation was suggested as a mitigating measure for other situations as well. For example, some respondents suggested that they would support the establishment of Marine Protected Areas, if they were compensated for the restrictions they would have to endure as a result (*"Fishers should be provided for"- L11*). It should be noted that local fishers in the Sporades Isles were originally in favour of the establishment of the National Marine Park of Alonissos because they had been promised compensation for damages caused by monk seals, and for the restriction of fishing grounds. However, this was never implemented and several years after the establishment of the Park, they were disappointed and were no longer as supportive of the Park. (Frangoudes and Alban, 2004; Oikonomou and Dikou, 2008).

Compensation programs most commonly provide re-imbursement to those who have experienced damages caused by wildlife (Nyhus et al., 2005). Compensation is also thought to strengthen the economic viability of small-scale fishers (Varjopuro, 2011). Such programs have been described as a good measure because they help people tolerate or endure the presence of protected/endangered species responsible for known damages (Wagner et al., 1997; Nyhus et al. 2005). Compensation programs can also help to reverse hostile opinions towards threatened species and to get affected social groups to look upon these animals more favourably. In the absence of compensation, revenge killings or poaching may be more likely (Nyhus et al., 2005). This was illustrated in responses provided by fishers of Crete, when they stated that unless they were compensated, they and/or their colleagues would start or continue killing turtles. Respondents who participated in this study stated that compensation, even if small, would go a long way towards supporting their livelihoods. It would also be perceived as a clear sign of support on the part of the state, rather than the perceived neglect of their sector as they experience it.

There are some caveats associated with compensation programs, especially when it comes to verification of damages. As illustrated by this study, however, compensation could be used to generate more support from fishers, both in terms of tolerance of threatened species and towards Marine Protected Areas.

"Ignore fisher's knowledge and miss the boat" (Johannes et al., 2001)

There is a great amount of knowledge on the marine environment and its resources that is held by small-scale fishers, regardless of their formal educational level. This includes knowledge about fish abundances, benthic environment, behavior and ecology of fish and environmental conditions. Further, this experiential wisdom has been accumulated over many years of direct contact with the sea, and has in many cases been passed down from one generation of fishers to the next. Fishers who participated in this study demonstrated a wealth of ecological knowledge. First of all, they were very vocal about the diminishing fish populations, and knowingly attributed such declines to unsustainable fishing practices such as overfishing, removing juvenile fish, catching fish during their spawning season and destruction of the benthic environment. Some described the effect of the removal of fish as a perturbation having cascading effects on the local ecosystem in ways very similar to how ecologists might explain such scenarios. Many recognized that sea turtles, dolphins and seals were part of the local ecosystem and labelled fishers themselves as intruders ("*We enter their element, not the other way around*"), and as a result they could not avoid them. Several respondents disagreed with the suggested removal of sea turtles, dolphins and seals from the area, recognizing that such measures were unfeasible (*"They are not sheep" – B03*). They reported being aware of global warming and climate change. They associated such changes with the displacement of fish populations and the problematic success of invasive species like pufferfish that took advantage of the warming sea water temperature to colonize much of the Greek coastline. They recognized that the creation of areas closed-off to fishing as part of MPAs might help to restore fish abundances even if it means that their fishing grounds would be reduced.

Fisher Ecological Knowledge (FEK) can be an immense help to researchers and policy makers as it can provide information that may improve management of fish populations, and/or restore ecosystems (Johannes et al., 2001). For example, local fisher knowledge indicated significant increases in the number of porpoises being killed due to boat strikes and by-catch in the Yangtze River (Turvey et al., 2013), while Sarda and Maynou (1998) were able to scientifically support and explain local fisher perception that Fridays were the best days to fish for shrimp. In both of these cases, the pairing of science, management and fisher knowledge benefitted multiple parties and led to better informed decision making.

Some biologists and policy makers tend to ignore fisher knowledge because it can be difficult to assess, evaluate and corroborate through robust scientific methods. However, to ignore FEK can sometimes have catastrophic consequences. The most prominent example of this was the collapse of cod fisheries in Newfoundland, Canada. For many years, in-shore fishers complained to the Canadian Department of Fisheries and Oceans (DFO) that they were experiencing declines in cod, suspecting that offshore fisheries were extracting so many cod fish that very few had the chance to migrate inshore and spawn. These complaints were scoffed at by biologists and ignored by DFO until the sudden and complete collapse of the fishery. This later led to the moratorium on cod fishing in 1992 (Kurlansky et al., 1997).

Another example is the historic challenge in cleaning up the Exxon Valdez oil spill in Prince William Sound Alaska in 1989. As the spill was happening, local fishers told clean up officials that currents would take the spill in a particular direction. The scientists decided that the oil would travel a different direction based on their scientific models. The fishers were right, however, and large sections of beach were oil-impacted as a result of containment gear being incorrectly positioned (Gordi, personal communication).

Including fishers and their experiential and cultural knowledge when making decisions might therefore be a key element in designing and implementing effective management decisions. First, fisher knowledge may provide fine-scale details about the area. These could improve the efficacy of management measures. Moreover, better inclusion of fishers in the decision-making process could lead to greater acceptance and support among fishers who are likely to be among the social groups most affected by such measures.

Opinions about MPA's – The fisher's point of view.

Marine Protected Areas usually include some restrictions for fishers. This can be cause for resentment (Badalamenti et al., 2000). Most of those who participated in this survey were in support of the establishment of Marine Protected Areas (76%), recognizing benefits especially for help to increase fish stocks. I also noted that support for protected areas increased to 87% among respondents when they were named "fishing refuges". The main reason given by respondents for opposing MPAs was the loss of fishing grounds (*"Where will the fisherman go to fish?"- B01*). Several of those who were in favour of MPAs stated that they and their colleagues should be given compensation to offset any associated restrictions on their activity. In addition, several fishers expressed doubts about how these MPAs would be implemented, stating that they were difficult to supervise, suggesting that several fishers would not comply with such restrictions. Unwillingness on the part of fishers to comply with fishing restrictions within MPAs has been documented in other studies (e.g. Silva et al., 2015) and it can seriously affect an MPA's effectiveness (Kritzer, 2004; Sethi and Hillborn, 2008).

Support for MPAs among fishers stems from the general idea that it will be "good for the fish". Cell and Roberts (2003) argue that marine reserves contribute to the build-up of biomass of commercially important and other species, which then "spill over" to areas adjacent to the reserves. Inside the reserve, fish populations should increase, while the marine areas outside them would benefit from the migration of excess fish and the dispersal of eggs and larvae (Bohnsack, 1998). Given the severe fish stock declines they have been experiencing, perhaps it is not surprising that respondents stated the willingness to "sacrifice" some of their fishing grounds in order to help restore fish stocks.

However, they did not unconditionally agree to MPAs being established. Some of them stated that MPAs should only be established after proper studies. Others did not want them to be permanent, stating that they should be seasonal, flexible and that closure locations should change over time. Flexibility within an MPA may be key to its local success. MPAs may fail due to poor design in relation to the conservation problems they are created to address; inappropriate planning and bad non-inclusive management processes; degradation of the unprotected surrounding area; and/or adverse effects resulting from the displacement of affected stakeholders and poor implementation (Agardy et al., 2011). A successful MPA needs clarity of definition, systematic testing of assumptions using indexes and adaptability to new information and conditions as they emerge, even if it may be difficult to implement (Agardy et al., 2003). Fishers may very well hold key pieces of knowledge, and otherwise be able to identify core criteria and other considerations that could improve MPA design, implementation, management and long term success.

Conclusions

This research was a first attempt at describing the views and perceptions of small-scale fishers on the island of Crete in order to combine this with scientific data on turtle behavior. Fishers contributed data about their interactions with sea turtles and other marine species, and discussed challenges for their profession and on MPAs. My findings indicate that small-scale fisheries interactions with sea turtles are more complex than originally conceived. Respondents suggested, for example, that interactions with sea turtles persist but that these should be viewed as part of a wider issue including interactions with other large marine vertebrates. This set of problematic interactions is intimately linked to the relationships between fishermen and fish. My findings also showed that compensation may offer multiple benefits as a conservation intervention—from reducing by-catch of protected species, to increasing support for MPAs. Thus, it may represent a good first step towards reducing mortality of turtles at sea. Further restrictions of fisher activity in Crete should only be contemplated after genuine deliberations with the fishing community. This should incorporate the local Fisher

Ecological Knowledge and integrate this professional and social group within the future decision-making processes.

My study also illustrated the value of surveying the opinions and beliefs of fishers. It includes new and useful revelations about small-scale fishermen, about their interactions with sea turtles and other species in Crete.

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Tables and Figures

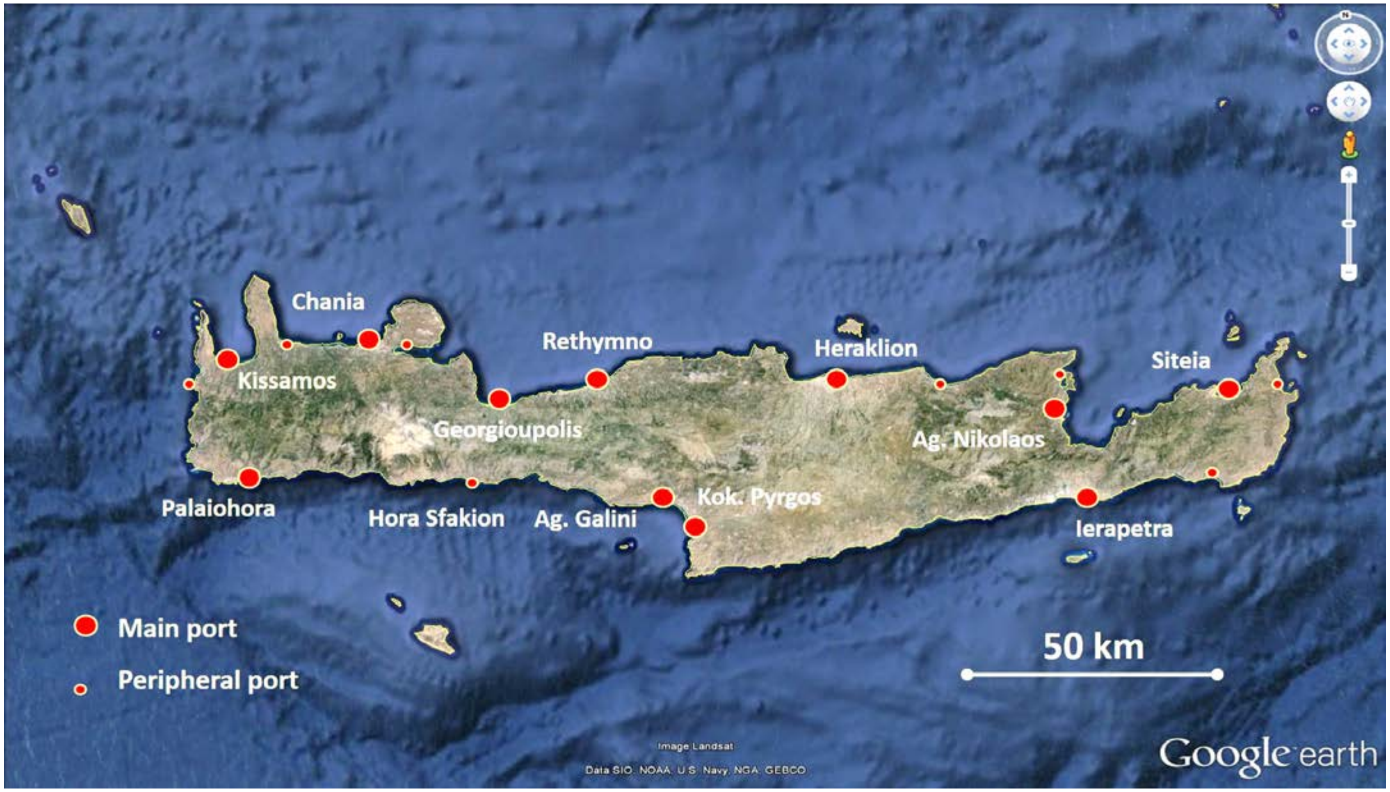

Figure 4.1. Map of Crete, including main and peripheral ports. Fishing vessels are typically registered at one of the central Coast Guard stations (Heraklion, Chania, Rethymno, Agios Nikolaos). They use one of the main ports as a base for their activities, however they may shift between peripheral ports across seasons so as to maximize yield. I visited each of these ports at least once over the course of this study.

Table 4.1. Demographic characteristics of fishers on Crete who participated in the study of fisher interactions with sea turtles. Abbreviations: F/V stands for Fishing Vessel.

Respondent profile								
Owner/skipper/Crew member		F/V owner/skipper	Crew member					
n=101		93%	7%					
Age (yrs)		< 24 - 34	35 - 44	45 - 54	55 - 64	65 - > 75		
n=101		9%	19%	33%	26%	13%		
Years as a professional fisherman	Mean	up to 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 40	> 41
n=101	30	9%	10%	9%	10%	21%	22%	19%
Education level:		Primary School	Middle/High School	Technical College or University				
n=101		38%	43%	19%				
Fishing is:		Full-time job	Part-time or Seasonal job					
n= 101		88%	12%					
How much of the household income is derived from fishing?		All/ More than 50	About 50%	Less than 50%				
n=101		70%	16%	14%				

Table 4.2. Fishing activity characteristics of respondents in the survey conducted on Crete. (*) Percentages do not add up to 100% because some respondents provided more than one answer.

Respondents' fishing activity characteristics

Boat length	Mean	< 5 - 8 m	9 - 12 m	13 - 15 m	
n=101	8.6 m	39%	57%	4%	

Crew size (incl. respondent)		1	2	3	4
n=101		30%	45%	22%	4%

Type of gear used		nets, trammel nets, etc.	Bottom longlines	Surface longlines	
(Out of total)		94%	77%	7%	

Fishing grounds (Distance from shore in nautical miles)	Mean	< 2 miles	2 - 5 miles	6 - 10 miles	More than 10 miles
n=97	5.3 miles	16%	42%	34%	8%

Where do you sell your catch?		On the boat or at port	Fish market or fish shops	Door-to-door, At local restaurants and hotels	Auction Sale Market (Chania)
(% of respondents)*		58%	53%	45%	8%

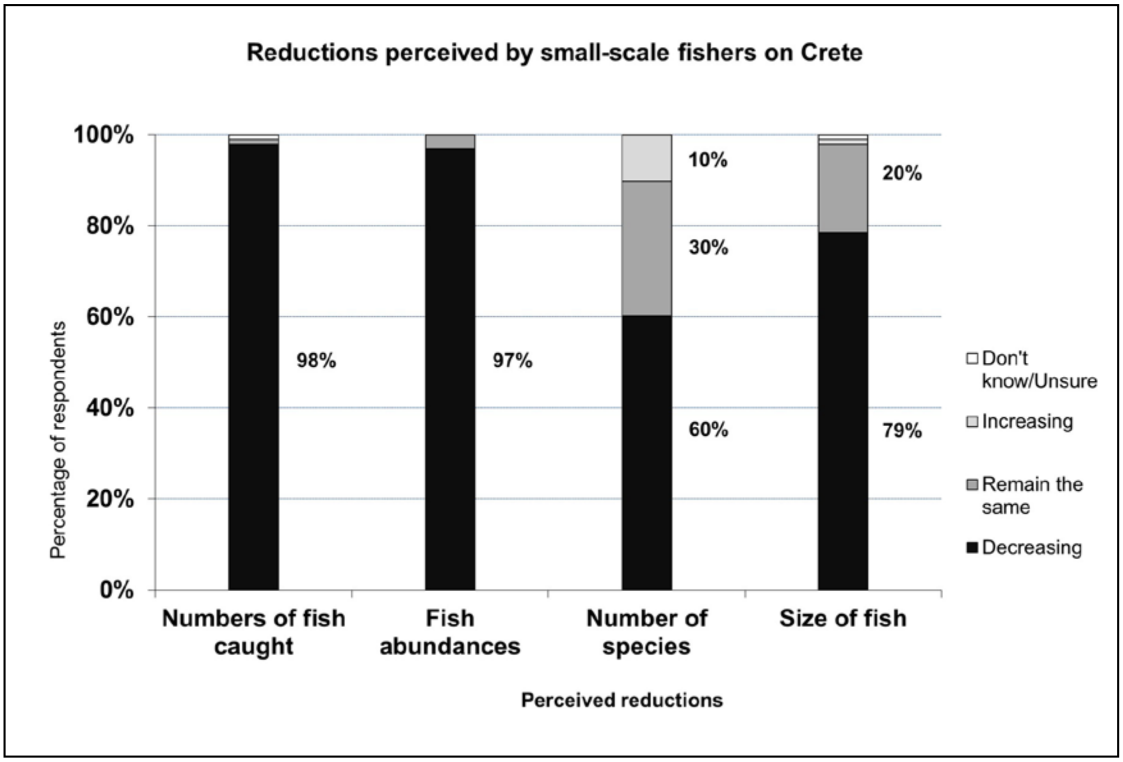

Figure 4.2. Reductions in catch perceived by small-scale fishers on Crete. Fishers observed reductions in numbers of fish caught and in fish abundances in general. Some fishers reported that number of fish remained the same (30%) or that it was increasing (10%) but they mostly attributed this to the appearance of new species that migrated from the Indian Ocean and the Red Sea through the Suez Canal (Lessepsian migration).

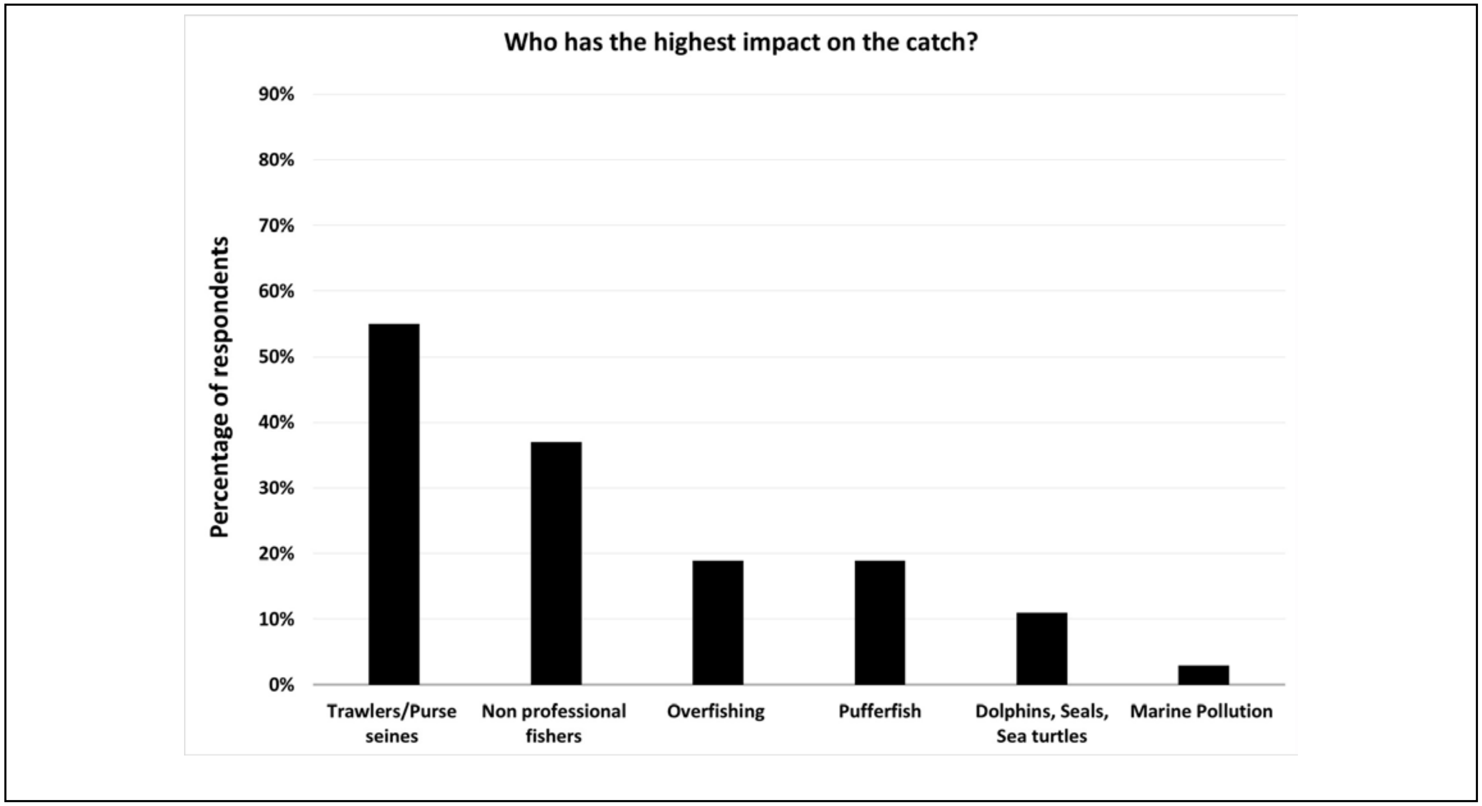

Figure 4.3. Perceptions of respondents in the study of fishers' interactions with sea turtles on Crete on which factor was having the greatest impact on their catch. Percentages did not add up to 100, because several fishers gave more than one factor as equally affecting their catch. I noted that competing fishing practices and overfishing in general were the factors having the highest impact and that large marine vertebrates like dolphins, seals and sea turtles were not reported to have such a high effect. Pufferfish were thought to have a significant impact on the catch due to the massive destruction they caused on a daily basis and the perception that they had eliminated cephalopod populations.

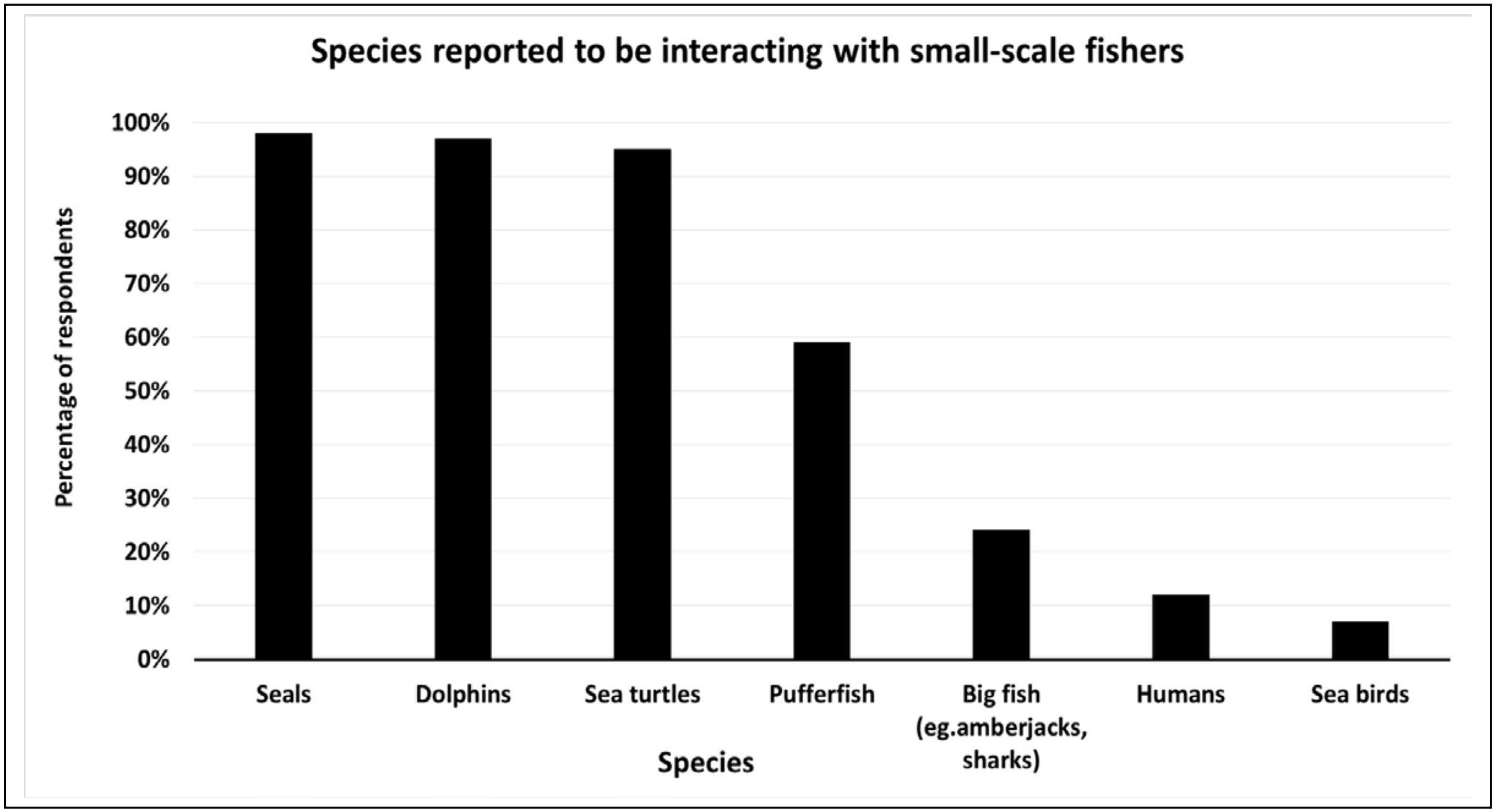

Figure 4.4. Species reported to be causing damage to fishing gear of fishers on Crete. Fishers described several species they were interacting with, therefore, the percentages did not add up to 100. It was interesting to note that even desirable fish species like amberjacks caused damage to gear and that on a few occasions even humans were reported to cause damage.

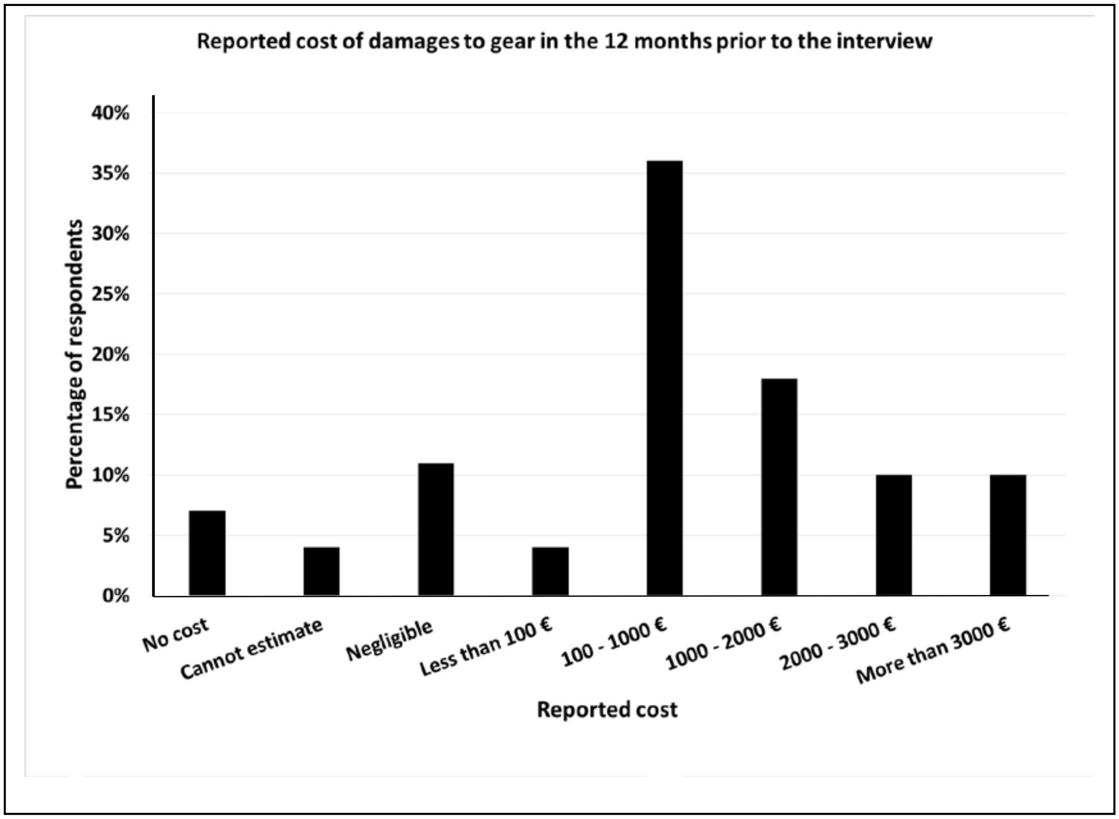

Figure 4.5. Estimated cost of damages caused by sea turtles on Crete in the 12 months prior to the interview. Amounts are given in Euro (€). Lowest amounts were for the most part reported by fishers predominantly using longlines – they stated that the cost to replace the line and hook was negligible. Most fishers (n=33) stated that they had spent between 500 and 2,000 €.

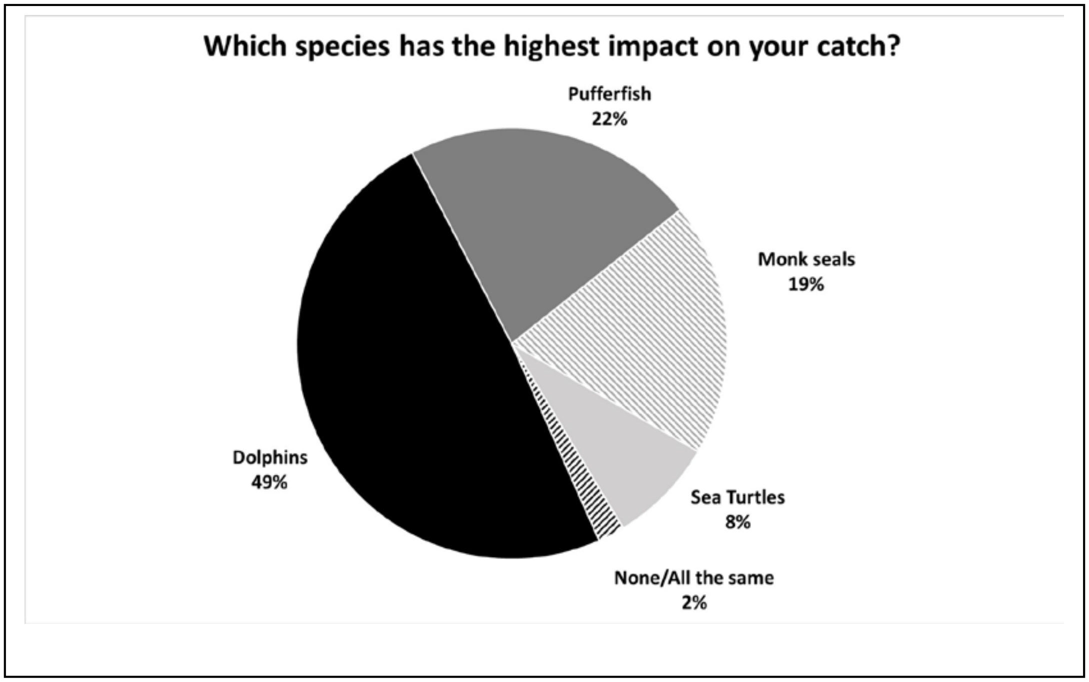

Figure 4.6. Reported opinion of fishers on Crete as to which marine vertebrate was causing the greatest amount of damage to their gear. Dolphins were perceived to be causing the most damage, with sea turtles ranking lower than all other species.

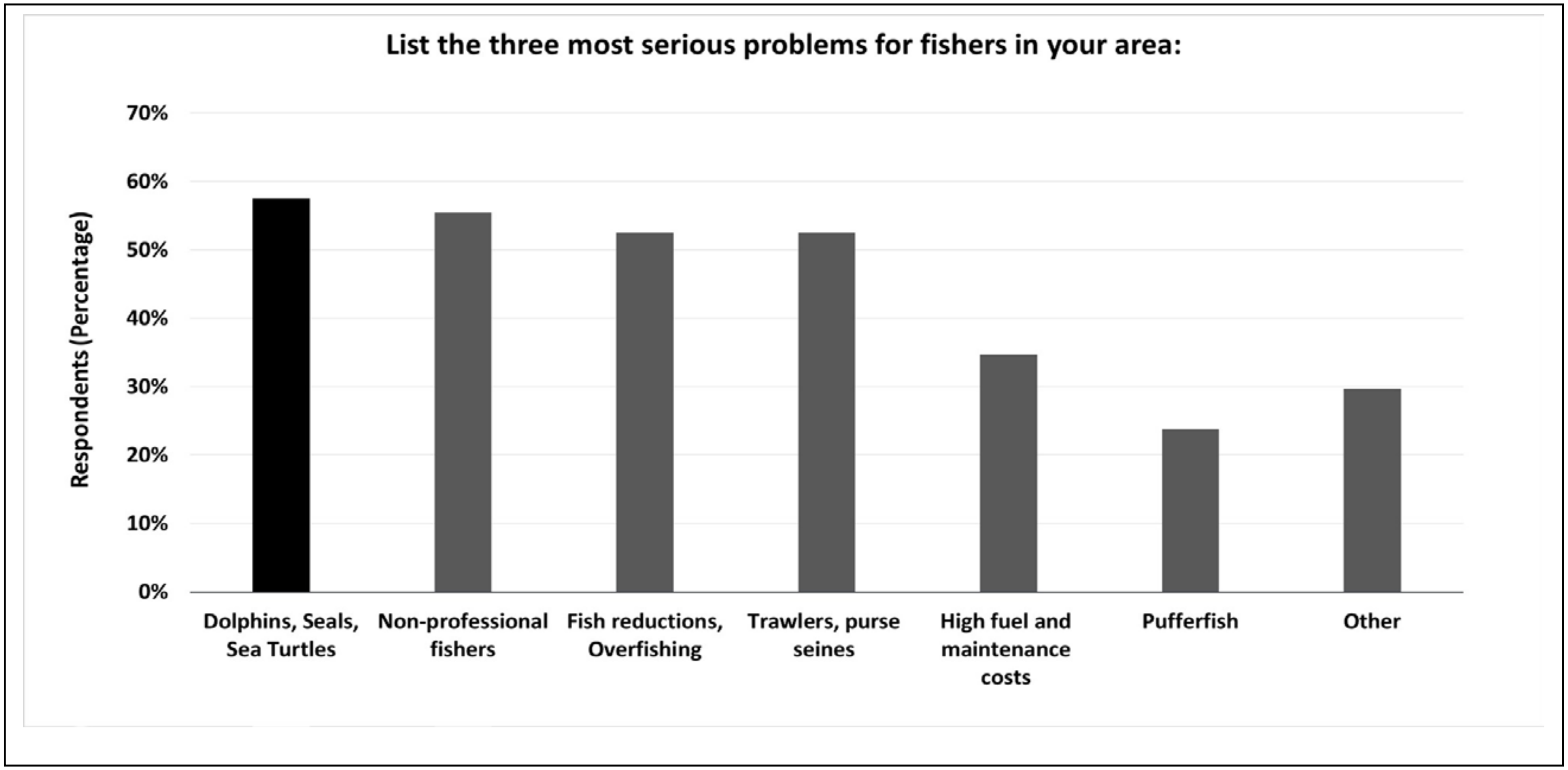

Figure 4.7. Top problems for the local fishery on Crete as reported by the respondents. Interactions with sea turtles, dolphins and seals combined rated highest amongst fishers' problems. Problems can be separated into subsets: on one hand there are those associated with environmental conditions like interactions with marine vertebrates and pufferfish while on the other are those having to do with fishing activity in general (competitive fisheries, high operating costs).

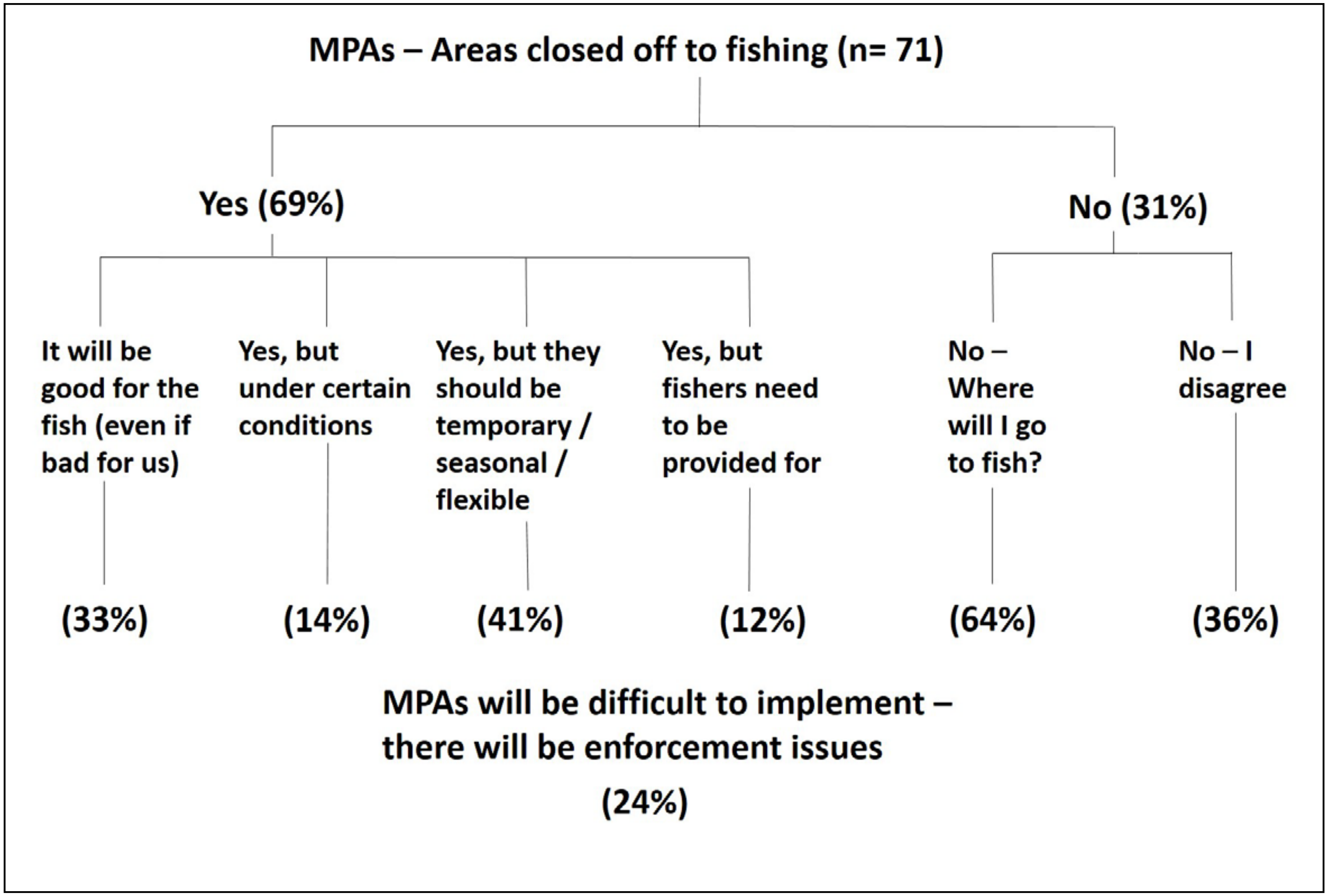

Figure 4.8. Schematic representation of fisher's opinions regarding Marine Protected Areas on Crete.

Chapter 5: Conclusions and conservation implications

My research indicated that an important part of the life cycle of loggerhead turtles nesting in Rethymno was linked to marine areas adjacent to the shore. Their internesting habitats go beyond the marine area offshore the nesting site and extend along the northern coast of Crete. Moreover, the turtles included in this study exhibited low site fidelity during the nesting season, indicating that their nesting habitat was dispersed across the island. It also appeared that not all of the females departed the site after the egg-laying season was complete, but instead they utilized the neritic habitats around the island for overwintering. These conclusions suggest that Crete should be considered as a single management unit for conservation purposes and I highly recommend that the island be resurveyed for possible shifts in core nesting habitats, because the observed decline in nesting activity in Rethymno may reflect a shift in nesting areas rather than an actual decline in population.

It is clear from my satellite telemetry data that the existing boundaries of the NATURA 2000 site did not include critical areas for sea turtles because the boundaries were established based on inadequate information. Therefore, management measures restricted to the site will be insufficient for protection of the loggerhead nesting population. Therefore, I recommend that the boundaries of the NATURA 2000 area should be redrawn based on the High Intensity and Medium Intensity Use areas of the turtles that were identified in this study. Moreover, because sea turtles frequent a much larger area of Crete for nesting and overwintering than previously known, protection measures should be expanded to include all of the areas used by the turtles. In addition, more research is needed in order to account for possible variability in the internesting habitat utilized by females and to identify usage of the area by male turtles and other size classes of sea turtles.

The diving behavior of loggerhead turtles nesting in Rethymno appeared to be driven by energy optimization strategies, with females spending long periods of time either resting on the sea bed or at the sea surface. Turtles used the entire water column but during the daytime appeared to show a preference for depths of less than 5 m or the water surface. As a result, turtles may be highly vulnerable while internesting in shallow waters close to the shore. These habitats were also intensely used by humans, increasing anthropogenic pressure on the population. Rethymno was heavily developed for tourism, and there were several watersports operators set up along the beach. Peak times of watersport activity coincided with the times that females spent at the surface, which potentially exposed them to injury from speed-boat activities. Further, significant small-scale fishing activity occured in the area, with the local fishers using predominately static nets and trammel nets. Some gear, trammel nets in particular, were left soaking for days at a time, increasing the risk to turtles of accidental capture and mortality. It is, therefore, of critical importance that mitigation measures be implemented to enhance protection of Rethymno loggerheads, especially during the nesting season. The clustering of turtles in a relatively proscribed area will make it easier to develop a more effective conservation plan.

Interactions of small-scale fisheries with sea turtles were complicated. It was clear that these represented a serious conservation challenge for sea turtles. Yet at the same time, fishers viewed fisher-turtle interactions as part of a wider issue including interactions with other large marine vertebrates. Such interactions were perceived as dynamic and multi-faceted and according to respondents, intimately linked to depleted fish populations. In terms of potential actions that could be taken to improve local sea turtle conservation, and fisher buy-in to it, compensation appeared as a key consideration. Compensation may have several benefits as a conservation intervention. It could help to reduce mortalities resulting from by-catch of protected species and could also increase support for MPAs. So serious consideration of adequate, attractive fisher compensation is a good first step towards reducing sea turtle mortality at sea.

My data indicated that further restrictions of fisher activity in Crete should only be contemplated after genuine deliberations with the fishing community and after incorporating the local Fisher Ecological Knowledge. Such undertakes should also be combined with measures to restore fish stocks in the area. There is a clear need to integrate local fishermen within current and future the decision-making processes.

Finally, my study indicated the depth of understanding that social science-based data collection and analysis of environment related opinions and beliefs of fishers can offer. Incorporating interdisciplinary methods such as I used can build case studies, and can generate interesting, complex data to be considered in regional, national and international conservation contexts, while offering more well-rounded information sets for use in decision making.

APPENDIX A: Questionnaire

INTERVIEW NUMBER: __________

ENGLISH VERSION

Opening Statement/Request for verbal consent

My name is Aliki Panagopoulou and this interview is part of my doctoral research at Drexel University. My research is about the relationships between sea turtles and small-scale fisheries in Crete. I am interested in fishermen's opinions about how sea turtles affect them and local fisheries, in their views of related problems and recommended solutions.

Thank you for participating in this survey: It should take approximately 50 minutes to complete.

<u>Participation in this project is voluntary. Survey responses will remain anonymous and no personal information will be kept in any form. Providing answers to this survey represents your agreement to contribute to this research. Feel free to ask me questions, skip any of the questions (no explanation needed) and/or to stop the survey at any time.</u>

All data will be confidential and stored securely. Only Dr. James R. Spotila (PhD Advisor), Dr. Zoë Meletis (PhD Committee member) and I will have access to the data. The data will be stored in a locked office and/or on university computers, and will be destroyed (by shredding, deletion and/or demagnetizing) after 15 years.

Survey results will not be made available to any other parties and will be used in academic research, publications and teaching. They will only be presented in anonymous and/or aggregated formats—individual answers will not be linked with detailed personal information. Any publications derived from these data will be available to academic audiences, the European Commission Fisheries Directorate – General, the Greek Ministry of Agriculture and Greek Research Institutes such as the Hellenic Center for Marine Research and the Fisheries Research Institute as well as the Fishermen's Associations of Crete.

If you have any complaints about this project or me, please contact my advisor, Dr. James R. Spotila (+1 215 895 2627), Dr Vellinski (Department Head of Drexel's Biodiversity, Earth and Environmental Science Department +1 215 299 1147) or Drexel University's Research Administration Office/HRP (+1 215 255 7857).

Thank you again, and please feel free to ask questions.

****

Part I. Demographics

First of all, I would like to ask you a few questions about you:

1. Gender: Male ☐ Female ☐ Other ☐

2. Age (years):

- ☐ A ≤24
- ☐ B 25 – 34
- ☐ C 35 – 44
- ☐ D 45 – 54
- ☐ E 55 - 64
- ☐ F 65 – 74
- ☐ G > 75

3. How long have you been a fisherman (approximate number of years)? ________________

3a. Are you fishing

- ☐ A full-time
- ☐ B part-time
- ☐ C seasonally
- ☐ D Other (pls specify) ____________________

4. Are you a

- ☐ A boat owner
- ☐ B skipper
- ☐ C working on a boat
- ☐ D Other (please specify) ___________________

5. Education: What is the highest level of school attended?

- ☐ A Primary School
- ☐ B High School/Lycaeum
- ☐ C Technical College/University
- ☐ D Other (please specify)

____

6. Is fishing your only source of income? ☐ Yes ☐ No

6a. If no, what are your other occupations?

i)______________________________

ii)______________________________

iii)_____________________________

6b. If no, how much of the family income is derived from fishing?
(Give an approximate estimate at an annual basis)

- ☐ A Less than half
- ☐ B About half
- ☐ C More than half
- ☐ D Don't know/Unsure

6c. If no, how much of your time is spent on fishing?
(Give an approximate estimate at an annual basis)

☐ A Less than half
☐ B About half
☐ C More than half
☐ D Don’t know/Unsure

6d. How much of your time is spent on non-fishing occupations?
(Give an approximate estimate at an annual basis)

☐ A Less than half
☐ B About half
☐ C More than Half
☐ D Don’t know/Unsure

Part II.: Fishing activity:

The next few questions are about fishing practices:

7. About the boat you are working on:

a. Boat Length (m): ____

b. Engine Power (HP): ____

c. # of people working on the boat (incl. you): ___

8. In which areas do you go fishing? i. Range ____

ii. Distance from the coast (miles) __________________

9. What types of gear do you use?

____

____

10. Where do you sell your catch? (Check all that apply)

☐ A From a boat/at port

☐ B Fish market/shop, or shops

☐ C Door to door to restaurants/hotels

☐ D Auction Sale Market

☐ E Other(s) (Please specify)

i) ___________________________________

ii) ___________________________________

iii) ____________________________________

10a. Of these, where do you sell most of your fish? __________________________

10b. Do you bring fish home for personal and family consumption? ☐ Yes ☐ No

The next few questions are about differences or changes that you may have noticed.

11. In the last 5-10 years, have you noticed any changes in your catch? ☐ Yes ☐ No

11a. Can you please explain in more detail?

____

____

12. *(skip this question if fisherman has not fished for more than five years)*

Compared with your catch 5 - 10 years ago*:*

a. Would you say that the number of fish that you catch is

☐ Increasing ☐ The same ☐ Decreasing ☐ I don't know/unsure

b. Would you say that fish abundances in the area are

☐ Increasing ☐ The same ☐ Decreasing ☐ I don't know/unsure

c. Would you say that the number of species of fish that you catch is

☐ Increasing ☐ The same ☐ Decreasing ☐ I don't know/unsure

d. Would you say that that the size of fish caught is

☐ Increasing ☐ The same ☐ Decreasing ☐ I don't know/unsure

13a. Would you like to say anything more about any of the changes above?

____

____

13b. Do you think that overall, these changes have benefitted you, or have cost you? Why?

____

____

13c. Do you think that they have benefitted the environment, or cost the environment? Why?

____

____

14. Some fishermen think that changes in fish numbers, size and species of fish caught are related to the reasons that I will now read. For each reason, please tell me how you rate their impact, if they do have any.

A. Pollution

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

B. Increased amount of fishing effort

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

C. Destruction of sea bottom due to trawling activity

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

D. Presence of sea turtles in the area (fish consumption, damages on gear)

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

E. Presence of dolphins, monk seals, and other marine mammals (includes fish consumption, damages on gear)

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

F. Establishment of marine protected areas

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

G. Restrictions on fishing activity – closed off areas

Very negative Negative Neutral/No impact Positive Very Positive I don’t know/unsure

H. Restrictions on fishing activity – banning of gear

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

I. Amateur fishing activity

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

15. Which of these reasons (Pollution, increased amount of fishing effort, destruction of sea bottom, damages caused by sea turtles, damages caused by dolphins and other marine mammals, establishment of marine protected areas, areas closed off to fishing, banning of gear) do you think has had the biggest impact?

____

16. Why?

____

____

17. Has it affected your fishing in a positive or negative way, and HOW?

____

____

18. Has it affected the local fishery in a positive or negative way and HOW?

____

____

Part III. Interactions with turtles and other species

Next, I will ask you a few questions about sea turtles and other species:

19. Are sea turtles ever caught in your gear? ☐ Yes ☐ No

19a. If yes, how many turtles did you catch in the last 12 months? _____

(give an approximate number)

19b. Using what gear? ____

20. Did these captures damage your gear? ☐ Yes ☐ No

20a. Can you describe the types of damage caused?

____

____

21. Do sea turtles sometimes cause damages without getting caught in your gear?

☐ Yes ☐ No ☐ I Don't know/Unsure

22a. If yes, how do you know that sea turtles are responsible for these damages?

____

____

____

22. During the past 12 months, how many workdays did you or a member of your crew spend mending gear damaged by sea turtles? (Give an approximate estimate)

____

23. During the past 12 months, what is the estimated cost (in €) of gear damage caused by sea turtles?

____

24. Are there other species that damage your gear? ☐ Yes ☐ No

24a. If yes, what species?

☐ A Dolphins
☐ B Monk seals
☐ C Other marine mammals
☐ D Humans
☐ D Sea birds
☐ E Fish (Please specify)______________
☐ F Other (Please specify) ____________

24b. Of all the species that you said damage your gear, which does the most damage? (estimate in €)

____

25. Overall, how much do you think sea turtles interfere with your fishing activity?

☐ A lot ☐ A little bit ☐ Not at all ☐ Don't know/unsure

26. Overall, how much of a threat do you think turtles are to the local fishery?

☐ A big threat ☐ A limited threat ☐ No threat ☐ I don't know/unsure

27. Do you think that sea turtles in Crete are increasing or decreasing as compared with?

a. 10 years ago Increasing Not changing Decreasing Don't Know/Unsure

b. The time you started fishing Increasing Not changing Decreasing Don't Know /Unsure

28. If you have noticed an increase or decrease in the turtle population, what is causing this change in your opinion?

Increase ____

Decrease ____

29. Some state that they dislike sea turtles for one of the following reasons. Please let me know to what degree you agree or disagree with them.

I dislike sea turtles because …

A. Sea turtles damage fishing gear

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

B. Sea turtles are bad luck

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

C. Sea turtles eat the fish we catch

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

D. Sea turtles can lead to areas being closed to fishing

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

E. Sea turtles can lead to increased regulations and fishing restrictions imposed by the government

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

F. Sea Turtles can lead to the creation of Marine Protected Areas

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

30. Would you like to add anything else about sea turtles?

____

____

Part IV. Small-scale fishing and management recommendations

31. What is the best part about being a fisherman?

____

____

32. What are the biggest challenges being faced by fishermen in Crete?

____

____

____

33. What impact do the following issues have on you and your fishing activity?

A. The high costs of fuel and maintenance

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

B. Trouble with access to markets/we and/or difficulty selling fish

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

C. Competition from trawling activity

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

D. Environmental impacts from illegal fishing practices (e.g. dynamite fishing, cyanide fishing)

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

E. Decreasing fish stocks

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

F. Gear damage by dolphins, seals, sea turtles or fish

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

G. Competition from amateur fishing activity

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

H. Fishermen from other areas using the local fishing grounds

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

I. Costs associated with the lack of government compensation for gear damage caused by protected species

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

J. Restrictions on types of fishing gear (e.g. banning of purse seine)

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

K. Fishermen being excluded from participating in decision making processes about fishing in the area

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

L. Fishermen having to avoid areas closed off to fishing

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

M. Pollution (trash, oil pollution, toxic outflows)

Very negative Negative Neutral/No impact Positive Very Positive I don't know/unsure

34. If you had to list the 3 most serious problems for small-scale fishermen in your area, what would these be?

1.____

2.____

3.____

35. In your opinion, what are the best solutions for these problems?

1. ____

2. ____

3. ____

36. This question includes suggestions of measures that could be taken. Please tell me how much you agree with each of the following statements:

The Government should:

A. Provide fishermen with financial compensation for gear damage caused by marine animals.

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

B. Consult small-scale fishing associations and groups when making decisions on fisheries

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

C. Consult with individual fishermen when making decisions on fisheries

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

D. Close off certain areas to **all** fishing activity

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

F. Close off areas **to some** fishing activities (e.g. no trawlers allowed; no amateur fishing allowed)

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

G. Restrict trawling activity to a minimum 3 nautical miles from the shore

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

H. Enforce existing fishing regulations

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

I. Create Marine Protected Areas (MPAs) in some areas, while allowing fishing in most places

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

J. Re-instate gear types that are restricted (e.g allow the use of purse seine again)

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

K. Conduct more research on fish stocks

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

L. Remove sea turtles from fishing areas and relocate them to conservation areas (e.g. Zakynhtos)

Strongly agree Agree Neutral Disagree Strongly disagree No opinion

M. Remove dolphins and seals from fishing areas and relocate them to conservation areas

Strongly agree   Agree   Neutral   Disagree   Strongly disagree   No opinion

N. Restore fish populations by using artificial reefs and other measures

Strongly agree   Agree   Neutral   Disagree   Strongly disagree   No opinion

O. Improve infrastructure available to fishermen (e.g. ports)

Strongly agree   Agree   Neutral   Disagree   Strongly disagree   No opinion

P. Improve provisions for transporting and selling fish

Strongly agree   Agree   Neutral   Disagree   Strongly disagree   No opinion

****

This is the end of the survey. This type of research would not be possible without the participation of people like you. Thank you very much for taking the time to participate !!

****

Results of this survey will be made available to all Fishermen's Associations of Crete. If you want to receive a copy, please text me at 6977 208648 with your contact information.

Α/Α ΣΥΝΕΝΤΕΥΞΗΣ: __________

GREEK VERSION

Αρχική Δήλωση/Αίτηση για προφορική συγκατάθεση συμμετοχής

Λέγομαι Αλίκη Παναγοπούλου και αυτή η συνέντευξη γίνεται στο πλαίσιο της έρευνάς μου για την απόκτηση διδακτορικού πτυχίου στο Πανεπιστήμιο Drexel των ΗΠΑ. Η έρευνά μου αφορά στις σχέσεις ανάμεσα στις θαλάσσιες χελώνες και τη μικρή παράκτια αλιεία. Ενδιαφέρομαι να μάθω τις απόψεις των παράκτιων ψαράδων για τις θαλάσσιες χελώνες και το βαθμό που επηρρεάζουν τους ίδους και την αλιεία στην περιοχή, καθώς επίσης και τη γνώμη τους για τα προβλήματά τους και τις λύσεις που προτείνουν.

Σας ευχαριστώ που συμμετέχετε σε αυτή την έρευνα – θα χρειαστούν περίπου 50 λεπτά για να ολοκληρωθεί.

<u>Η συμμετοχή σε αυτή την έρευνα είναι εθελοντική. Οι απαντήσεις που θα δοθούν θα παραμείνουν ανώνυμες και δεν θα τηρηθεί κανενός είδους προσωπικό δεδομένο. Από τη στιγμή που αρχίζετε να συμπληρώνετε το ερωτηματολόγιο, θεωρούμε ότι δίνετε τη συγκατάθεσή σας να συμμετάσχετε στην έρευνα αυτή. Μπορείτε να κάνετε όσες ερωτήσεις θέλετε, να αρνηθείτε να απαντήσετε οποιαδήποτε ερώτηση ή να διακόψετε τη συνέντευξη όποτε θέλετε χωρίς να δώσετε εξηγήσεις.</u>

Όλα τα επιστημονικά δεδομένα θα παραμείνουν εμπιστευτικά και θα αποθηκευτούν με ασφάλεια. Πρόσβαση στα δεδομένα εκτός από μένα θα έχει ο Dr. James R. Spotila (ο επιβλέπων καθηγητής μου) και η Dr. Ζωή Μελέτη (μέλος της Επιστημονικής μου Επιτροπής). Τα δεδομένα θα τηρούνται ασφαλισμένα σε χώρο και υπολογιστές του Πανεπιστημίου Drexel και θα καταστραφούν μέσω απομαγνητισμού/φορμαρίσματος σκληρών δίσκων και καταστροφέα εγγράφων μετά από 15 χρόνια.

Τα αποτελέσματα της έρευνας δεν θα δοθούν σε τρίτους και θα χρησιμποιηθούν αποκλειστικά για ερευνητικούς σκοπούς, δημοσιεύσεις και διαλέξεις. Τα αποτελέσματα θα παρουσιαστούν μόνο συγκεντρωτικά και δεν θα μπορούν να συνδεθούν με κανένα προσωπικό δεδομένο. Όσες δημοσιεύσεις προκύψουν από αυτά τα δεδομένα θα κοινοποιηθούν στην επιστημονική κοινότητα, τη Γενική Διεύθυνση Αλιείας της Ευρωπαϊκής Επιτροπής, τη Διεύθυνση Αλιείας του Υπουργείου Αγροτικής Ανάπτυξης, Ερευνητικά Ινστιτούτα όπως το ΕΛΚΕΘΕ και το Ελληνικό Ινστιτούτο Αλιείας και τους Αλιευτικούς Συλλόγους της Κρήτης.

Οποιαδήποτε παράπονα έχετε για την έρευνα αυτή ή για μένα προσωπικά μπορείτε να επικοινωνήσετε με τον επιβλέποντα καθηγητή μου τον Dr. James R. Spotila στο 001 215 895 2627, τον επικεφαλής του τμήματος Βοιοποικιλότητας, Γαίας και Επιστήμης του Περιβάλλοντος Dr. David Vellinski στο 001 215 299 1147 ή τη Κεντρική Διοίκηση Έρευνας του Πανεπιστημίου Drexel στο 001 215 255 7857.

Σας ευχαριστώ και πάλι και μη διστάσετε να με ρωτήσετε οτιδήποτε.

****

Μέρος Α. Δημογραφικά στοιχεία

Θα ήθελα πρώτα να κάνω κάποιες ερωτήσεις για σας:

1. Φύλο: Άντρας ☐ Γυναίκα ☐ Άλλο ☐

2. Ηλικία (έτη):

☐ A ≤ 24
☐ B 25 – 34
☐ C 35 – 44
☐ D 45 – 54
☐ E 55 - 64
☐ F 65 – 74
☐ G > 75

3. Πόσο καιρό είστε επαγγελματίας ψαράς; (Σε χρόνια); _______________

3α. Η αλιεία για σας είναι δουλειά

☐ A Πλήρους απασχόλησης
☐ B Μερικής απασχόλησης
☐ C Εποχιακή
☐ D Άλλο (παρακαλώ διευκρινήστε)
____

4. Είστε:

☐ A Πλοιοκτήτης
☐ B Καπετάνιος
☐ C Μέλος πληρώματος σε σκάφος
☐ D Άλλο (Παρακαλώ διευκρινήστε) __________________

5. Εκπαίδευση;

☐ A Δημοτικό
☐ B Γυμνάσιο/Λύκειο
☐ C Πανεπιστήμιο/ΤΕΙ
☐ D Άλλο (Παρακαλώ διευκρινίστε)
____

6. Η Αλιεία είναι η μοναδική πηγή εισοδήματος για σας; ☐ Ναι ☐ Όχι

6α. Αν όχι, τι άλλες δουλειές κάνετε;

i) _____________________________
ii) _____________________________
iii) _____________________________

6β. Πόσο περίπου από το οικογενειακό εισόδημα προέρχεται από την αλιεία;

☐ A Λιγότερο από το μισό

☐ B Περίπου το μισό

☐ C Πάνω από το μισό

☐ D Δεν ξέρω/Δεν απαντώ

6γ. Πόσο από το χρόνο σας αφιερώνετε στις άλλες επαγγελματικές σας δραστηριότητες;

☐ A Λιγότερο από το μισό

☐ B Περίπου το μισό

☐ C Πάνω από το μισό

☐ D Δεν ξέρω/Δεν απαντώ

6δ. Αν όχι, πόσο από το χρόνο σας αφιερώνετε στο ψάρεμα;

☐ A Λιγότερο από το μισό

☐ B Περίπου το μισό

☐ C Πάνω από το μισό

☐ D Δεν ξέρω/Δεν απαντώ

ΜΕΡΟΣ Β: Σχετικά με την αλιευτική σας δραστηριότητα:

Οι επόμενες ερωτήσεις έχουν να κάνουν με την αλιευτική σας δραστηριότητα:

7. Σχετικά με το σκάφος που δουλεύετε:

a. Μήκος (m) _____
b. Μηχανή (σε ίππους): _____
c. Πλήρωμα (μαζί με σας) ____

8. Σε ποιες περιοχές ψαρεύετε συνήθως? i. Εύρος____

ii. Απόσταση από την ακτή σε μίλια ______________

9. Τι αλιευτικά εργαλεία χρησιμοποιείτε?

____

____

10. Πού διαθέτετε την ψαριά σας; (τσεκάρετε όσα ισχύουν)

☐ A Στο λιμάνι/Στη βάρκα

☐ B Σε ιχθυοπωλεία

☐ C Σε εστιατόρια/ξενοδοχεία

☐ D Ιχθυόσκαλα

☐ E Άλλο

(Παρακαλώ διευκρινίστε)

i) ______________________

ii) ______________________

iii) ______________________

10α. Από αυτά, πού διαθέτετε το μεγαλύτερο μέρος της ψαριάς σας; ______________________

10b. Χρησιμοποιείτε μέρος της ψαριάς σας για οικογενειακή κατανάλωση;

☐ Ναι ☐ Όχι

Οι επόμενες ερωτήσεις σχετίζονται με διαφορές ή αλλαγές που τυχόν παρατηρήσατε

11. Τα τελευταία 5 – 10 χρόνια έχετε παρατηρήσει αλλαγές στην ψαριά σας;

☐ Ναι ☐ Όχι

11α. Μπορείτε να επεκταθείτε λίγο στο θέμα;

____

____

12. *(Αν ο ψαράς είναι στο επάγγελμα λιγότερο από 5 χρόνια, προχωρήστε στην επόμενη ερώτηση)*

Σε σύγκριση με 5 – 10 χρόνια πριν:

a. Θα λέγατε ότι ο αριθμός αλιευμάτων που πιάνετε:

☐ Αυξάνεται ☐ Παραμένει ίδιος ☐ Μειώνεται ☐ Δεν ξέρω/ Δεν είμαι βέβαιος

b. Θα λέγατε ότι οι πληθυσμοί των ψαριών και άλλων αλιευμάτων γενικότερα

☐ Αυξάνονται ☐ Παραμένουν ίδιοι ☐ Μειώνονται ☐ Δεν ξέρω/ Δεν είμαι βέβαιος

c. Θα λέγατε ότι τα είδη που πιάνετε

☐ Αυξάνονται ☐ Παραμένουν ίδιοι ☐ Μειώνονται ☐ Δεν ξέρω/ Δεν είμαι βέβαιος

d. Θα λέγατε ότι τα μεγέθη αλιευμάτων

☐ Αυξάνονται ☐ Παραμένουν ίδιοι ☐ Μειώνονται ☐ Δεν ξέρω/ Δεν είμαι βέβαιος

13α. Θέλετε να συμπληρώσετε κάτι σχετικό με τις αλλαγές αυτές που παρατηρήσατε?

____

____

13β. Σε γενικές γραμμές, θεωρείτε ότι οι αλλαγές αυτές σας έχουν ωφελήσει ή σας έχουν βλάψει; Γιατί;

____

____

13γ. Θεωρείτε ότι οι αλλαγές αυτές ωφέλησαν ή έβαλψαν το φυσικό περιβάλλον; Γιατί;

____

____

14. Κάποιοι ψαράδες θεωρούν ότι οι αλλαγές σε αριθμό, ποικιλία και μέγεθος αλιευμάτων οφείλονται σε κάποιον ή κάποιους από τους παρακάτω λόγους. Για καθένα από αυτούς τους λόγους, μπορείτε να αξιολογήσετε αν έχουν θετικό ή αρνητικό αντίκτυπο;

Α. Ρύπανση (σκουπίδια, πετρέλαιο, απόβλητα)

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

B. Αυξημένη αλιευτική προσπάθεια

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

C. Καταστροφή βυθού από συρόμενα εργαλεία

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

D. Παρουσία χελωνών στην περιοχή (τρώνε ψάρια, κάνουν ζημιές στα εργαλεία)

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

E. Παρουσία δελφινιών, φωκών και άλλων θηλαστικών στην περιοχή (τρώνε ψάρια, κάνουν ζημιές στα εργαλεία)

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

F. Δημιουργία θαλάσσιων προστατευόμενων περιοχών

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

G. Περιορισμοί στην αλιεία – περιοχές αποκλεισμένες για την αλιεία

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

H. Περιορισμοί στην αλιεία – απαγόρευση ορισμένων αλιευτικών εργαλείων

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

I. Ερασιτεχνική αλιεία

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

15. Ποιος από τους παραπάνω λόγους (ρύπανση, αυξημένη αλιευτική προσπάθεια, καταστροφή βυθού από συρόμενα εργαλεία, ζημιές που προκαλούν θαλάσσιες χελώνες, ζημιές που προκαλούν δελφίνια φώκιες και άλλα ζώα, δημιουργία θαλάσσιων προστατευόμενων περιοχών, περιοχές αποκλεισμένες στην αλιεία, απαγόρευση αλιευτικών εργαλείων) θεωρείτε ότι έχει τον μεγαλύτερο αντίκτυπο για σας;

____

16. Γιατί;

____

____

17. Έχει επηρρεάσει την αλιευτική σας δραστηριότητα θετικά ή αρνητικά και με ποιο τρόπο;

____

____

18. Έχει επηρρεάσει την αλιεία στην περιοχή θετικά ή αρνητικά και με ποιο τρόπο;

____

____

ΜΕΡΟΣ Γ. ΑΛΛΗΛΕΠΙΔΡΑΣΗ ΜΕ ΘΑΛΑΣΣΙΕΣ ΧΕΛΩΝΕΣ ΚΑΙ ΑΛΛΑ ΕΙΔΗ

Στη συνέχεια θα σας κάνω μερικές ερωτήσεις σχετικά με τη γνώμη σας για με τις θαλάσσιες χελώνες και άλλα είδη:

19. Πιάνονται ποτέ χελώνες στα εργαλεία σας;

☐ Ναι ☐ Όχι

19α. Αν ναι, πόσες περίπου χελώνες πιάστηκαν τους τελευταίους 12 μήνες? _______________

19β. Χρησιμοποιώντας τι εργαλεία? ____

20. Αυτές οι συλλήψεις προκάλεσαν ζημιές στα εργαλεία σας;

☐ Ναι ☐ Όχι

20α. Μπορείτε να περιγράψετε τι ζημιές σας προκάλεσαν;

____

____

21. Υπάρχουν φορές που οι χελώνες κάνουν ζημιά στα εργαλεία σας χωρίς όμως να πιάνονται σε αυτά;

☐ Ναι ☐ Όχι ☐ Δεν ξέρω/Δεν είμαι βέβαιος

21α. Αν ναι, πώς καταλαβαίνετε ότι αυτές οι ζημιές έχουν προκληθεί από θαλάσσιες χελώνες;

____

____

22. Τους τελευταίους 12 μήνες πόσες περίπου μέρες αφιερώσατε επιδιορθώνοντας ζημιές που προκλήθηκαν από θαλάσσιες χελώνες; (εσείς ή κάποιος από το πλήρωμά σας)

____

23. Κατά τον τελευταίο χρόνο, ποιό υπολογίζετε ότι ήταν το κόστος των ζημιών που προκλήθηκαν από θαλάσσιες χελώνες ? (Σε Ευρώ)

____

24. Υπάρχουν άλλα είδη που προκαλούν ζημιές στα εργαλεία σας;

☐ Ναι ☐ Όχι

24α. Αν ναι, τι είδη?

☐ A Δελφίνια	☐ E Θαλασσοπούλια
☐ B Φώκιες	☐ F Ψάρια (Διευκρινίστε)_____________
☐ C Άλλα θηλαστικά	☐ G Άλλο (Διευκρινίστε) _____________
☐ D Άνθρωποι	

24β. Από όλα τα είδη που αναφέρατε ότι σας κάνουν ζημιές, ποιο (ή ποια) προκαλούν τις μεγαλύτερες; (κόστος σε Ευρώ)

____

25. Σε γενικές γραμμές, πόσο νομίζετε ότι οι θαλάσσιες χελώνες παρεμποδίζουν την αλιευτική σας δραστηριότητα;

☐ Πάρα πολύ ☐ Λίγο ☐ Καθόλου ☐ Δεν ξέρω/Δεν είμαι βέβαιος

26. Σε γενικές γραμμές πόσο μεγάλη απειλή θεωρείτε ότι είναι οι θαλάσσιες χελώνες για την παράκτια αλιεία στην περιοχή;

☐ Μεγάλη απειλή ☐ Περιορισμένη απειλή ☐ Καθόλου απειλή ☐ Δεν ξέρω/Δεν είμαι βέβαιος

27. Κατά τη γνώμη σας οι θαλάσσιες χελώνες στη Κρήτη αυξάνονται ή μειώνονται σε σύγκριση με

α. Πριν 10 χρόνια

Αυξάνονται Δεν υπάρχει αλλαγή Μειώνονται Δεν ξέρω/Δεν είμαι βέβαιος

β. Όταν ξεκινήσατε το ψάρεμα

Αυξάνονται Δεν υπάρχει αλλαγή Μειώνονται Δεν ξέρω/Δεν είμαι βέβαιος

28. Αν παρατηρήσατε αλλαγές στους πληθυσμούς των θαλάσσιων χελωνών ποιες είναι οι αιτίες κατά την άποψή σας;

Αύξηση στον πληθυσμό

____

____

Μείωση στον πληθυσμό

____

____

29. Κάποιοι δηλώνουν ότι δεν συμπαθούν τις θαλάσσιες χελώνες για κάποιον από τους παρακάτω λόγους. Σε ποιο βαθμό συμφωνείτε ή διαφωνείτε μαζί τους;

Αντιπαθώ τις θαλάσσιες χελώνες γιατί...

A. Οι χελώνες προκαλούν ζημιές στα αλιευτικά εργαλεία

Συμφωνώ απόλυτα   Συμφωνώ   Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

B. Οι θαλάσσιες χελώνες είναι γρουσουζιά

Συμφωνώ απόλυτα   Συμφωνώ   Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

C. Οι χελώνες μας τρώνε τα ψάρια

Συμφωνώ απόλυτα   Συμφωνώ   Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

D. Η παρουσία θαλάσσιων χελωνών μπορεί να οδηγήσει σε δημιουργία περιοχών όπου απαγορεύεται η αλιεία

Συμφωνώ απόλυτα   Συμφωνώ   Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

E. Η παρουσία θαλάσσιων χελωνών μπορεί να οδηγήσει σε επιπλέον κανονισμούς και περιορισμούς στην αλιευτική δραστηριότητα

Συμφωνώ απόλυτα   Συμφωνώ   Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

F. Η παρουσία θαλάσσιων χελωνών μπορεί να οδηγήσει στη δημιουργία προστατευόμενων περιοχών

Συμφωνώ απόλυτα   Συμφωνώ   Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

30. Θέλετε να προσθέσετε κάτι άλλο σχετικό με τις θαλάσσιες χελώνες;

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ΜΕΡΟΣ Δ. Μικρή παράκτια αλιεία: Προβλήματα και λύσεις

31. Ποια είναι η καλύτερη πλευρά του επαγγέλματος του ψαρά κατά τη γνώμη σας;

____

____

32. Ποια είναι τα μεγαλύτερα προβλήματα που αντιμετωπίζουν οι ψαράδες της Κρήτης;

____

____

____

33. Τι αντίκτυπο έχουν σε σας και την αλιευτική σας δραστηριότητα τα παρακάτω ζητήματα;

A. Τα κόστη καυσίμων και συντήρησης είναι πολύ υψηλά

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

B. Δεν υπάρχει εύκολη πρόσβαση τις αγορές/ δυσκολευόμαστε να πουλήσουμε τα ψάρια μας

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

C. Μας ανταγωνίζονται τα συρόμενα εργαλεία

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

D. Αντίκτυπος στο περιβάλλον από παράνομη αλιευτική δραστηριότητα (ψάρεμα με δυναμίτη, υδροκυάνιο)

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

E. Οι πληθυσμοί των ψαριών μειώνονται

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

F. Καταστροφή εργαλείων από δελφίνια, φώκιες και θαλάσσιες χελώνες ή άλλα ψάρια

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

G. Έχουμε ανταγωνισμό με την ερασιτεχνική αλιευτική δραστηριότητα

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

H. Ψαράδες που έρχονται από μακρινές περιοχές να ψαρέψουν στα τοπικά αλιευτικά πεδία

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

I. Δεν υπάρχει καμία πρόβλεψη από το κράτος για αποζημιώσεις για ζημιές που προκαλούν τα προστατευόμενα είδη

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

J. Περιορισμοί στη χρήση εργαλείων (π.χ. απαγόρευση βιντζότρατας)

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

K. Είμαστε αποκλεισμένοι από τη διαδικασία λήψης αποφάσεων για την αλιεία στην περιοχή

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

L. Υπάρχουν περιοχές αποκλεισμένες για το ψάρεμα στις οποίες δεν μπορούμε να ψαρέψουμε

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

M. Ρύπανση (σκουπίδια, πετρέλαιο, απόβλητα)

Πολύ αρνητικό Αρνητικό Ουδέτερο Θετικό Πολύ θετικό Δεν ξέρω/Δεν είμαι βέβαιος

34. Αν έπρεπε να επιλέξετε τα 3 σημαντικότερα προβλήματα για τη μικρή παράκτια αλιεία στην περιοχή σας, ποια θα ήταν αυτά;

1.____

2.____

3.____

35. Κατά τη γνώμη σας ποια είναι η λύση για τα προβλήματα αυτά;

1.____

2. ____

3. ____

36. Αυτή η ερώτηση περιλαμβάνει κάποια προτεινόμενα μέτρα που μπορούν να παρθούν από την κυβέρνηση. Πόσο συμφωνείτε με τις παρακάτω προτάσεις;

Η κυβέρνηση θα πρέπει να φροντίσει ώστε:

A. Να αποζημιώνονται οι ψαράδες για τις ζημιές που προκαλούν τα διάφορα θαλάσσια ζώα

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

B. Να ζητάται η γνώμη των Συλλόγων και Ομοσπονδιών των Επαγγελματιών Αλιέων προτού παρθούν αποφάσεις για την αλιεία

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

C. Να ζητάται η γνώμη μεμονωμένων ψαράδων προτού παρθούν αποφάσεις για την αλιεία

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

D. Να θεσπιστούν περιοχές όπου απαγορεύεται **τελείως** το ψάρεμα σε όλες του τις μορφές

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

F. Να θεσπιστούν περιοχές όπου θα επιτρέπονται **μόνο ορισμένες** αλιευτικές δραστηριότητες (πχ μόνο δίχτυα και παραγάδια)

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

G. Να περιοριστεί η δραστηριότητα των συρόμενων εργαλείων σε απόσταση τουλάχιστον 3 ν.μ. από την ακτή

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

H. Να εφαρμοστεί η σχετική νομοθεσία και κανονισμοί

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

I. Να δημιουργηθούν Αλιευτικά Καταφύγια σε ορισμένες περιοχές, επιτρέποντας το ψάρεμα στις υπόλοιπες

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

J. Να επιτραπεί η χρήση εργαλείων που έχουν απαγορευτεί (π.χ. να επιτραπεί και πάλι η βιντζότρατα)

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

K. Να γίνουν περισσότερες έρευνες για τα ιχθυαποθέματα

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

L. Να απομακρυνθούν οι θαλάσσιες χελώνες από την περιοχή και να περιοριστούν σε προστατευόμενες περιοχές (π.χ. Ζάκυνθος)

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

M. Να απομακρυνθούν τα δελφίνια και οι φώκιες και να περιοριστούν σε προστατευόμενες περιοχές (π.χ. Αλόνησος)

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

Ν. Να αποκατασταθούν τα ιχθυαποθέματα μέσω της δημιουργίας τεχνητών υφάλων και άλλων μέτρων

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

Ο. Να βελτιωθούν οι υποδομές για τους ψαράδες (πχ τα λιμάνια/αλιευτικά καταφύγια)

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

Ρ. Να βελτιωθούν οι υποδομές για τη διακίνηση και διάθεση των αλιευμάτων

Συμφωνώ απόλυτα Συμφωνώ Είμαι ουδέτερος Διαφωνώ λίγο Διαφωνώ τελείως Δεν έχω γνώμη

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Εδώ τελειώνει το ερωτηματολόγιο. Χωρίς εσάς και τους συναδέλφους σας δεν θα μπορούσα ποτέ να κάνω αυτού του είδους την έρευνα. Σας ευχαριστώ πολύ για το χρόνο που μου αφιερώσατε! !

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Θα στείλω τα αποτελέσματα της έρευνάς μου σε όλους τους Συλλόγους Επαγγελματιών Αλιέων στην Κρήτη. Αν θέλετε και εσείς να λάβετε αντίγραφο, στείλτε μου μήνυμα με τα στοιχεία σας στο 6977 208 648.

VITA

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EDUCATION

2013	Ph.D., Environmental Science, Drexel University, Philadelphia PA.
1989	BSc, National & Kapodistrian University of Athens, Greece.

PROFESSIONAL EXPERIENCE

2011– 2015	Teaching Assistant, Drexel University, Philadelphia PA
2004–2010	Projects Coordinator and Conservation Officer, ARCHELON, Greece
1998–2003	Coordinator for ARCHELON's Project of Crete
1989–1998	Foreign Language Teacher

AWARDS AND HONORS (Selection)

2014	Archie Carr Student Award: Runner Up for Conservation, 35th ISTS
2015	International Travel Award, Office of International Programs ($0.75K)
2014	William L. McLean III Fellowship (12.5K)
2014	Archie Carr Student Award: Runner Up for Conservation, 34th ISTS
2013	Claudio T. Elia Memorial Fellowship ($6K)
2010	Lee Smith Travel Fellowship ($2K)

PROFESSIONAL SOCIETIES AND APPOINTMENTS (Selection)

2013-Present	Society for Conservation Biology
2013-Present	Herpetologist's League
2005-Present	IUCN/SSC – Marine Turtle Specialist Group
2001-Present	International Sea Turtle Society (Member of BoD: 2011 – 2016)

SELECT PUBLICATIONS AND ABSTRACTS

Panagopoulou A., Meletis Z.A., Margaritoulis D and Spotila J.R. 2015. Hook, line and thinkers: Understanding complex perceptions of fisher-turtle interactions in context (Crete, Greece). In Proceedings of 35th Annual Symposium in Sea Turtle Biology and Conservation, Dalaman, Mugla, Turkey, 18-24 April 2015.

Panagopoulou A., Meletis Z.A., Margaritoulis D and Spotila J.R. 2014. Untangling fishermen-turtle relationships: perceptions of sea turtle interactions with small-scale fisheries, in Crete, Greece. In Proceedings of 34th Annual Symposium in Sea Turtle Biology and Conservation, New Orleans, Louisiana, USA, 10-17th April 2014.

Margaritoulis D and **Panagopoulou A.** 2010. Chapter on Greece in Casale, P. and Margaritoulis, D. (Eds.) 2010. Sea Turtles in the Mediterranean: Distribution, threats and conservation priorities. Gland, Switzerland: IUCN. 294pp.